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Reports on Current European/Middle Eastern Science

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ESN INFORMATION BULLETIN

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This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large

Commanding Officer ..... CAPT Terry J. McCloskey, USN
Scientific Director ..... James E. Andrews
Editor ..... C.J. Fox

ACOUSTICS

Structural Acoustics Research at ONERA (France) ..... **David Feit** 1

The structural acoustics research being pursued at ONERA in France is reviewed. Recent work is in the area of fluid-structure interaction, wave propagation in composites and "fuzzy structure" calculations for vibration response.

Underwater Acoustics Research at the Royal Aerospace Establishment – a Review of Michael Buckingham's Work ..... **David Feit** 3

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Selected highlights of this conference, held in July 1988 at the University of Oxford, UK, are discussed. Topics include semiconductor and metal surfaces, molecular imaging, electrochemistry, and lithography.

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The status of an on-going activity in free electron laser (FEL) research in various countries and regions of the world as reflected in the presentations of this conference, held in August-September 1988 at Jerusalem, Israel, is reviewed. The author concludes that FEL research is on the threshold of a new era, in which the applications of the lasers (to scientific research and to solution of real-world problems in medicine and industry) will become more important than the understanding of the devices themselves.

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ACOUSTICS

Structural Acoustics Research at ONERA

by David Feit. Dr Feit is the Liaison Scientist for Acoustics and Mechanics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until January 1990 from the David Taylor Research Center, where he is a research scientist in the Ship Acoustics Department.

Introduction

ONERA, the acronym for the Office National et d'Etudes et de Recherches Aerospatiales, has been in existence since 1946. Although it was founded to "develop, orient, and coordinate research in the field of aeronautics" it has in recent years conducted research relevant to naval applications, and this work is coordinated through the office of The General Technical Director by F. Jouaillec. ONERA currently employs more than 2100 people, more than one-third of whom are scientists and engineers. ONERA is publicly owned, but operates as an industrial and commercial scientific organization under the supervision of the Direction des Recherches Etudes et Techniques (DRET). It conducts fundamental and applied research for both industry and the French Ministry of Defense (MOD). As an example of its work breakdown, the operating budget in 1986 was FF956 million about ($150 million), 38 percent of which was MOD funding while approximately 60 percent came from non-MOD contracts.

On a recent visit to the main laboratories and headquarters located at Chatillon-sous-Bagneaux, a close-in suburb just south of Paris, I was hosted by Dr. Roger Ohayon, who is head of the Mechanics and Structural Calculations Group, a part of the Structures Department. Also joining me for this visit was Dr. Albert Tucker, a Scientific Officer in the Mechanics Division from ONR Headquarters, Washington. Some of the work at ONERA is familiar to the US community since a general review of the structural acoustics work being conducted there was presented by Ohayon at the Workshop on Structural Acoustics held in Woods Hole, Massachusetts, in August 1986. This meeting was organized and chaired by Dr. Tucker.

The Structures Department at ONERA works generally in the areas of:

- Structural mechanics
- Aeroelasticity
- Damage mechanics.

With Dr. Ohayon during our meeting were several members of his group who gave brief descriptions of their work: Bernard Nicolas-Vuillierme, Danielle Osmont, and Denis Duhamel. I shall describe these investigations subsequently.

Also involved in acoustics research is the Acoustics Group, headed by Dr. Gerard Fournier, which is part of the Physics Department. In the past much of its efforts were directed towards aeroacoustic-related phenomena, but more recently, a large share of its efforts has also been in the area of hydroacoustics. I hope to visit this group and report on its activities at a later date.

Sound Radiation From Vibrating Fluid-Loaded Structures

In recent years, Ohayon's group, under the sponsorship of the Direction des Construction Navales (DCN), has looked at the problem of vibrating structures interacting with an external dense and compressible medium. This work has been pursued using both a theoretical and experimental approach. In the low-frequency range where the acoustic wavelengths are large compared to the diameter of the long, slender body that is vibrating, a modal analysis of the structure is combined with a Helmholtz integral solution of the acoustic field. This yields a coupled set of equations for the structural modal amplitudes which are then solved numerically. The radiated acoustic field is obtained from the Helmholtz integral representation by simple quadratures. This approach is not particularly new but is worth developing when any organization or institution wishes to understand the radiating characteristics of a particular structure. The expertise and computer programs necessary to implement such an approach are not easily transferred from one organization to another. In parallel with the theoretical approach, and as a means of validating and gaining confidence in the analytics a set of experiments have been performed on a cylindrical structure that is made up of five distinct compartments. These experiments were carried out at the Lake Castillion facility in southern France. The other researchers involved in these efforts were J.J. Angelini, P.M. Hutin, G. Piazzoli, and C. Soize.

Interaction With US Scientists

As I mentioned earlier, the general approach discussed in the above paragraph has been used elsewhere. A number of US laboratories have developed computer programs for the structural acoustic response of vibrating structures. The most difficult part of the problem is the prescription of the radiation loading presented by the ambient acoustic medium. One approximate approach that has demonstrated a fair amount of success in application was developed by T. Geers while at the Lockheed Palo Alto Research Laboratories. The essential step here is to replace the fluid pressure acting on the structure by terms proportional to the local normal velocity and accelerations. These approximations have been labeled the "Doubly Asymptotic Approximation" (DAA) and various versions have been proposed over the years. ONERA is aware of these methods and sponsored a visiting scientist, Bernard Nicolas-Vuillierme, who spent a year at Lockheed gaining experience in the use of this technique. He has now returned to ONERA and is continuing to work in this area. He has recently submitted a paper to the *Journal of Acoustical Society of America* on a formal derivation and verification of the DAA methods which he discussed during our meeting.

Minimizing of Radiated Noise by Use of External Treatments

In work related to the use of composite structures for the reduction of radiated acoustic fields, Danielle Osmont is pursuing a project on the acoustics of a layered structure wherein he is attempting to determine the parameters necessary to minimize the radiated field. The structure is modeled as an elastic layer that is subjected to an acoustic field and is separated from the water medium by another set of layers whose thickness, density, and compressibility are variable. These are allowed to vary in order to obtain a minimum in the acoustic power radiated. In pursuing this optimization problem large simplifications are necessary, such as representing the layer displacements by single scalar potentials rather than vector potentials, and limiting the number of layers to a small number such as two or three. This work has just recently been initiated so no new specific results were presented.

Modeling Composites as Two-Dimensional Periodic Structures

Denis Duhamel, a recent honors graduate of l'Ecole Polytechnique, which I understand is one of the élite educational institutions in France, was the last staff member to discuss his work. He has been looking into the problem of wave propagation in composite media which are characterized as two-dimensional elastic continua with arrays of scatterers dispersed periodically throughout the structure. He is hoping to use a low-frequency approximation to effect an homogenization so that effective elastic parameters can be obtained. Early results indicate that attenuation in stop bands is less effective for two-dimensional media than that which exists in a one-dimensional continua. This investigation like the one using external treatments is also in its early stages, but Ohayon expressed great confidence that more interesting results would soon be forthcoming. Ohayon indicated that there would be a great deal of interaction between his group and the Material Department's ceramics group with regard to the work on wave propagation in composites. It is my impression that this is a very hot topic of research at ONERA and is receiving a great deal of attention.

Vibration of Fuzzy Structures

Although C. Soize was not present at our discussions we did briefly discuss the work that Soize had been pursuing relevant to the mid-frequency range vibrations of realistic structures. This work was motivated by the oft-noted observation that when measuring the frequency response function of a physical model structure – i.e., one that is a small-scale idealized version of a realistic full-scale structure – one usually finds a much finer grained response function for the model than for the full-scale structure. In order to quantify this phenomenon Soize has developed an approach to the calculation of structural response functions which captures the essence of this result. In this approach he suggests that a structure can be thought to be made up of a "master structure," which is rather easily modeled in a deterministic fashion and essentially models the outer smooth envelope of the structure. To this structure one attaches a "fuzzy structure" which represents the large number of internal degrees of freedom necessary to describe the various pieces of equipment and subsidiary structures that make up the insides of the total structure. The physical characteristics of this latter structure are certainly less well defined than those of the envelope structure. Therefore it can be thought of as being a "fuzzy structure" describable more in terms of a set of added degrees of freedom whose mass and stiffness properties as well as attachment point to the main structure are only known approximately and described in a probabilistic sense. Calculations of frequency response functions for such composite structures show a relatively smooth and less spiky variation than those of the main structure. I am planning to learn more about this approach and its applicability to structural acoustics problems by talking with Soize himself in the near future.

Discussion

I was very impressed with the caliber of the work being conducted by Dr. Ohayon and his staff. Ohayon displays great vigor and enthusiasm in his approach to problems, and this translates into the excellent output of his group. He is a strong advocate of a combined theoretic-experimental approach, which is necessary in this age of the computer. Computational capabilities now threaten to outrun our ability to experimentally understand a physical phenomenon in the sense that it is sometimes easier to simulate a physical experiment numerically than to actually make the physical measurement. It is therefore refreshing that Ohayon strongly resists this trend and insists on comparison to physical experiment even though much of the work of his group relies on computer solution of problems. I look forward to further visits to ONERA to meet other individuals pursuing work relevant to structural acoustics. I very definitely see the possibility of US/French collaboration on the "fuzzy structure" calculation approach and technique.

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Underwater Acoustics Research at the Royal Aerospace Establishment–A Review of Michael Buckingham's Work

by David Feit.

Introduction

The Royal Aerospace Establishment (RAE), formerly the Royal Aircraft Establishment, located in Farnborough, Hampshire, England, has a long tradition of acoustics research related to noise and vibration of aeroacoustic origin. Although perhaps less well known there is also a fair amount of underwater acoustics research being conducted at this establishment.

This work comes about in support of the Royal Air Force's mission in antisubmarine warfare (ASW) which requires use of sonobuoys in detecting and classifying submarines. The theoretical acoustics work is carried out in the Air-Sea Warfare Division of the Mission Management Department. This division is headed by Dr. Dennis Stanfield who is well known to the US ASW community. Dr. Stanfield was an exchange scientist at the Naval Air Development Center during the early 1970's.

Theoretical Acoustics Group

During my visit I spent most of my time with Dr. Michael Buckingham, who is an Individual Merit Senior Principal Officer (IM/SPSO) and heads the Theoretical Acoustics Group. He has been with RAE since 1974 and in recent years has spent two periods in the US as an exchange scientist, the first of which was at the Naval Research Laboratory (NRL) during the period 1981 to 1983. The size of the group staff varies depending on the project which Buckingham is pursuing at any given time, and how much technical support is required. Working with him at the present time is Peter Martinson, a very capable young scientist who has been on staff at RAE for about 10 years. The primary research interest of Dr. Buckingham's group at the present time is the study of noise mechanisms responsible for ambient noise in the Arctic Ocean. This interest developed while he spent a year (1986-87) as an exchange scientist at the Massachusetts Institute of Technology (MIT). There he was exposed to the large amounts of noise data from the Marginal Ice Zone Exercise (MIZEX). His principal contacts at MIT were Professors Dyer and Baggeroer of the Ocean Engineering Department.

Modeling of Ambient Noise in the Arctic Ocean

While at MIT Dr. Buckingham, in addition to his research activities, acted as adviser to a number of students in both the Ocean Engineering and Civil Engineering Departments. As a result of one such collaboration he published a paper (Buckingham and Chi-fang, 1987) with Chi-fang Chen, a doctoral student working with Ira Dyer. In this work they suggested the impact of ice flows on the surface as a possible noise generating mechanism in the Arctic Ocean below the marginal ice zone. They used data from recordings of ambient noise made in the Fram Strait in 1984 during the MIZEX. This data in the form of time series and power spectra were used to postulate a theoretical model of the noise generation process which was found to be generally consistent with some of the main features in the data. The noise is spikey in character and reveals a spectral density which varies inversely with

frequency raised to some power, which in a period of 5 days varied from 1.0 to a high value of 3.0. This paper concentrated on the bumping of ice flows as the principal noise generating mechanism.

To model the situation each ice flow was assumed to act as a neutrally buoyant fluid-filled sphere with a different sound speed than that of the surrounding water (shear stresses in the ice are neglected and the sound speed of the ice is assumed to be twice that of water). During a collision the ice sphere distorts and the ensuing vibrations of the sphere radiate sound. The model was further simplified to include only the zeroth order mode, in which the sphere pulsates uniformly. The higher order modes were assumed to be less significant contributors to the far field radiation. The solution to this problem is well known and is presented in terms of the frequency, the sound speed ratio, and the magnitude of the pressure pulsations.

The magnitude of the pressure pulsations were determined by the details of the collision process between any two ice flows. During contact the ice flows can crack and break as well as deform due to the force of impact. The cracking and breaking give rise to higher frequency noise than was of interest to this study, but the deformation process gives rise to low-frequency noise, less than 2 kHz, and it is this process that is modeled.

During the deformation process the spherical-shaped flow was assumed to be incompressible. As the contact between the ice flows progresses the sphere radius also increases, so that it acts as a simple acoustic source. The changing radius was determined using a simple linear mass, spring, and damper for the deformation process. The source strength so determined was then convolved with the fundamental solution determined earlier to yield a time-dependent pressure distribution. The controlling parameters are the quality factor related to the damping in the collision process, the volume of the flow, and a frequency which also depends on the mechanical properties of the flow, in particular, its size. The typical sizes of the flows can range from a few meters to several hundred meters, giving rise to pulse oscillations over several orders of magnitude, as is observed in the MIZ ambient noise.

The result for a single collision was generalized to a distribution of collisions over the ice surface and the results further modified to account for the effect of the pressure release surface, thereby modifying the directivity of the generated noise field. The representation used in this early analysis gave results which are in reasonable agreement with observations of the noise in the MIZ. However, some of the assumptions made in arriving at the model are difficult to justify physically.

Since Buckingham has returned to the UK this past October he has been looking at more refined models of the collision and radiation processes in the ice flows. In particular he is looking at the case of a solid sphere representation of an ice flow. In this model the sphere is assumed to be an elastic continuum which supports both compressional and shear waves simultaneously. The motion of such an object is further complicated by the presence of the fluid outside the sphere. At the present time he is looking at the vibration excited by a spherically symmetric source arbitrarily located within the sphere in the absence of fluid loading. Ultimately the fluid loading effects which will substantially complicate the picture will be included. Dr. Buckingham is fortunate to have Peter Martinson working with him on this problem due to the complexity of the problem and the unwieldy algebraic expressions that arise in the evolution of the solution. While visiting with Buckingham we discussed various ways of visualizing the results so as to gain some more physical insight into the complicated vibration patterns that emerge with changing frequency.

Other Sources of Ambient Noise

Also while at MIT Buckingham worked with Professor W.K. Melville of the Civil Engineering Department. Melville is interested in the mechanics of wave breaking at the air/sea interface, and has demonstrated the important role of wave breaking in the generation of bubbles and gas transfer at the interface (Melville and Rapp, 1985). Buckingham is planning to collaborate with Melville on studies related to the noise generated in conjunction with this process. In particular they are planning to make acoustic measurements in the wave tank at MIT to study the coherence characteristics of the noise.

In past years Buckingham was involved with the development of the Horizontal Array Random Position (HARP) system. In this system about a dozen sonobuoys are dropped into position and deployed to their operating depth. While at that position a small number of the sonobuoys are activated as pingers, and the relative positions of all the sonobuoys are determined using a triangulation scheme. Once the positions are known the beam patterns of the distributed array can be determined and used to investigate the sound field. According to Buckingham this system has been demonstrated successfully on a number of occasions and he is now hoping to make use of it to record certain underwater acoustic events – especially, underwater geysers that can be found in the waters off the UK.

Affiliation with the University of Southampton

In addition to his duties at RAE Dr. Buckingham maintains close ties with the University of Southampton Institute of Sound and Vibration Research (ISVR) where he acts as an adviser to students and occasionally lectures. ISVR has a long-established reputation in aeroacoustics

and vibrations research, and Buckingham is seeking to develop underwater acoustics research at the university. Working with a doctoral student he has developed a finite element code for underwater sound propagation in a channel with an elastic bottom. He was instrumental in bringing Dr. David Chapman of the Canadian Defense Research Establishment (DREA) to ISVR to enhance the ISVR efforts in underwater acoustics. I will be reporting on acoustics research and education at ISVR in a later article.

Other Activities in the Air-Sea Warfare Division

I was also introduced to Dr. L.E.C. Ruskell, who heads the Sonobuoy R&D group which consists of himself and six other professional staff members. He showed me some actual sonobuoys and discussed how each of them works. In the course of his conversation he indicated that many of the designs were very similar to US designs of the same vintage.

In addition to these two groups there are a number of other groups in the division. These are: Sonobuoy Engineering and Trials, Signal and Data Processing, Future ASW Systems, Active Systems, and the *COL Templer* Crew Members. The *COL Templer* is a seagoing vessel used to obtain actual full-scale trial data. Besides this ship, the division has three aircraft at its disposal, including a NIMROD and a BAC 111.

Discussion

I was impressed with the fact that Dr. Buckingham can pursue his research interests over a fairly wide range of topics as long as they are in some way related to underwater acoustics. This is probably due to management's recognition of his excellent contribution to more specific project-related work over the preceding years of his career at RAE. As a result of his two stays in the US and his contribution to the underwater acoustics activities of the Acoustical Society of America, he is well known to the underwater acoustic community in the US. His efforts in helping to expand underwater acoustics activities at the ISVR are to be applauded, and we look forward to increased collaboration between the US and UK scientists in this field.

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8/10/88

BEHAVIORAL SCIENCES

German Research on the Cognitive Consequences of Predecision and Postdecision Motivational States

by William Crano. Dr. Crano was the Liaison Scientist for Psychology in Europe and the Middle East for the Office of Naval Research's London Branch Office from June 1986 through August 1988. He has returned to Texas A&M University, where he is a Professor of Psychology.

As Julius Caesar crossed the Rubicon with his legions, thereby igniting civil war in Rome, he is said to have stated, "*Alea iacta est*" – The die is cast. We cannot know what was in his mind at that time, but it is a good bet that his thoughts then were very different from those he entertained before deciding upon this fateful course of action. His predecisional thoughts must have been occupied with the issues of cost and gain, of the likelihood of success and failure, of the implications of his act for himself and for Rome. Having made the decision and crossed the Rubicon, however, his creative mind probably turned to much more practical issues of implementation: How are the legions to be deployed and supplied; where is resistance most likely to arise; who will fight; who will run – in short, how will the campaign be won.

The different mindsets, as they are called, which guide and influence the process of cognition, have been the focus of intensive study by Professor Heinz Heckhausen (Head of Munich's Max Planck Institute for Developmental Psychology) and his associate, Dr. Peter Gollwitzer. This report will outline the theory and some of the empirical findings of this very productive research

group. It is my impression that Heckhausen's work will stimulate fundamental changes in research undertaken on motivation in psychology (cf. Heckhausen, 1986). And, given the importance of motivation in almost all other realms of the field, it is reasonable to assume that this program of study will have important implications for psychology as a whole.

Earlier Ideas

Two distinct research traditions on motivation are evident in the psychological literature. The first was instituted at the turn of the century by Ash (1905, 1910), who introduced to psychology the idea of a "determining tendency." A determining tendency is defined as a force that guides behavior in the service of an intended course of action. However, how the course of action became "intended" – i.e., why a certain outcome was seen as desirable, and worth working for – was never addressed in Ash's work (or in the work of the European will psychologists as a whole, of which Ash's theory is representative).

A second tradition in motivation research, exemplified by the expectancy-value models, are much more commonly represented in today's psychology (cf. Atkinson, 1964). Such models are focused most strongly on the conditions and processes that foster a choice of one course over another. In expectancy-value models, to predict motivation some value of the desirability of an outcome is combined with the actor's subjective estimate of the probability of his achieving the outcome. So, if a person views a highly desirable outcome as moderately likely, we would expect that his motivation to achieve the outcome (as measured either in terms of his self-report or actual behavior) would be higher than if the likelihood of the outcome were viewed as remote.

The expectancy-value approaches have been developed in the context of predecisional processes; that is, they have to do with the thoughts and actions of people who are in the process of making a choice, not with their thoughts and the consequent behaviors they implement after having done so. Some attempts have been made to "translate" this essentially predecisional model to the postdecisional arena (Atkinson and Raynor, 1974), but these extensions have been less than completely successful. This is not to criticize the expectancy-value models; indeed, they have provided psychological research in motivation with a firm foundation on which considerable useful research has been based. However, is it clear that a more inclusive approach that accounts not only for predecision, but for postdecision mental and behavioral activity as well, is needed.

Motivation and Volition

Heckhausen and Kuhl (1985) recently put forward the reasonable proposition that motivation differs from predecisional to postdecisional contexts, since we are concerned with very different issues before, or after having made, a decision to act in some way (as with Caesar crossing the Rubicon). More controversially, they also hypothesized that not only would the content of pre- and postdecision thoughts differ, but that fundamentally different cognitive processes would be brought on line depending upon status of the decision (pre vs post). In their model, they differentiated predecisional motivation from postdecisional *volition*.

Motivation is the (predecisional) state in which all information relating to a particular choice of action or goal is (or may be) considered. Foremost among the forms of information sought will be the available costs and incentives for one goal (or action) over another, expectations of success, etc. The motivational state passes to the volitional state when the individual makes a decision, or when it is made for him, e.g., by outside forces.

Volition is the (postdecisional) state of mind that is focused on implementation of the chosen decision. Its central focus is when and how to act in order to maximize the likelihood of attaining the chosen outcome. In this state, considerations of (prechoice) available alternatives are irrelevant, and as such are disregarded. It is the implementation of the decision, rather than a consideration of the decision's correctness, that lies at the heart of this mindset.

If this view is correct, then very different information processing activities should be brought into play as a function of the motivational or volitional nature of the individual's mental state. Receptivity to different types of information should occur as a consequence of state, as should variations in breadth of attention, central and incidental learning processes, and other factors to be discussed over the course of this report. Following are some experimental investigations of the motivation/volition distinction.

General Overview of the Experiments

To provide a reasonable method of testing his ideas, Heckhausen devised a general experimental paradigm in which research subjects could be examined immediately before, or immediately after, having made a decision. In all ways other than the timing of their decision, the subjects who had been randomly assigned to one or another of the experimental conditions were indistinguishable.

In the research, subjects were asked to consider two stimulus arrays that would serve as the raw data for a test of their creativity, which was to follow. The stimulus arrays consisted of two sets of seemingly unrelated pictures, which the subjects would use in the development of a creative story. The subjects' initial task was to choose one of the two arrays, which they then would (purportedly) use in the test. The importance of the test was stressed, and

given the nature of its subject matter, it is reasonable to assume that the college-age students who served as subjects would take the experimenter's injunctions seriously. They were enjoined from forming hasty decisions, and advised to consider all possible aspects of the stimulus materials.

Half the subjects in the experiment are asked to make a decision, and then to perform a task. The task differs from study to study, and performance on the tasks represent the central focus of investigation from study to study. The other half of the subject sample are asked to perform the critical task before coming to a decision. Differences between pre- and postdecisional groups allow for a decision regarding the validity of Heckhausen's speculations, because subjects in these two conditions should be in different (i.e., motivational versus volitional) mindsets.

This overview provides a general picture of the methodology employed in the studies to be discussed. The dependent measures chosen for consideration vary from one study to the next, as will be seen. The systematic nature of this series is to me illustrative of the proper utilization of the scientific method in social research; moreover, the results that were gathered in this set of experiments shed considerable light on the validity of the Rubicon model, as Heckhausen has chosen to call his theory.

Experiment 1: Thought Contents

Heckhausen has postulated that people are motivated to attend to different features of the environment as a consequence of the stage at which they find themselves in the decision-making process. To put this idea to the test, half the subjects of Experiment 1 were asked 90 seconds after viewing the last of the stimulus slides, but before making their choice of stimuli, to list their most recent thoughts. This same request was made of the remaining subjects 90 seconds after they had made their choice of stimuli.

Thoughts were classified as motivational, volitional, or task-irrelevant, by scorers who were unaware of the measurement condition of the respondent whose answers they were judging. Frequencies of the three types of thoughts were analyzed, and the results disclosed some interesting (and statistically significant) differences as a consequence of experimental condition:

- On average, the frequency of motivational thoughts of subjects who had not yet made a choice of stimulus material was nearly five times that of subjects in the postdecision measurement condition.
- Conversely, the frequency of motivational thoughts of subjects who had made their choice of stimulus material was three times that of the respondents in the predecision condition.
- Task-irrelevant thoughts were twice as frequent in the postdecision group than in the predecision group, suggesting that predecisional thought processes are more driven by task considerations than postdecisional processes.

Experiment 2: Receptivity to Information

The Rubicon model fosters the prediction that people who are in a predecisional state of mind are likely to process information differently from those who have already formed their choice. Individuals in a predecision mindset are more likely to be in an information-search mode than those who have already made their choice. As such, "predecisionals" should be more receptive to new information, and thus more able to process it. If this hypothesis is correct, then the short-term memory span of those in a predecisional state of mind should appear greater than that of postdecision individuals.

To test this hypothesis, Heckhausen and his colleagues performed a study that in general design was very similar to that of Experiment 1. The major difference between the studies (in addition to the change of dependent variable) was that a learning test was administered before the commencement of the stimulus choice (or decision-making task). In the learning trials, subjects were exposed to short lists of words, and asked to memorize them. The first two lists contained five one-syllable nouns (house, tree, art), the two middle lists, six nouns, and the last two lists seven nouns. After a list was read, the subject was to repeat the words it contained, in order. Performance on this task served as a baseline indicator of each subject's short-term memory span.

Then, as in Experiment 1, subjects were asked to make a choice between one of two sets of stimulus pictures, which would be used (purportedly) to facilitate their performance on a personally relevant test of creativity. Also as in the first study, half the subjects were interrupted before their decision, and asked to work briefly on another task. The interposed task involved their learning five short lists of words. The remaining half of the subject sample learned the lists immediately after having made their choice.

Did the groups differ in learning score as a consequence of this manipulation? As before, the results were very interesting, and fully compatible with theoretical expectations:

- The baseline learning test disclosed no initial differences between predecisional and postdecisional subjects. In other words, the two groups did not differ initially on short-term memory span. Differences between the groups on subsequent tests, therefore, cannot reasonably be attributed to preexisting differences in memory capacity.

- However, the predecision subjects showed a marked (statistically significant) improvement in memory span between baseline and posttest measurements, while baseline and posttest performance of postdecision subjects were indistinguishable.

These are exciting findings. They suggest that the learning performance of subjects who were initially indistinguishable could be altered substantially, and in a predictable manner, by varying the time – predecisional or postdecisional – at which the performance is undertaken. Memory performance of subjects in the midst of a decision – in a motivational mindset, to use Heckhauser's phrasing – was improved relative to that which they had displayed only minutes previously. Performance of subjects who had already decided upon a course of action was unchanged from that which they displayed on the pretest. Not incidentally, the similarity of pretest performance of the two groups in conjunction with later learning difference suggests that the motivational mindset actually improves memory, not that the volitional mindset attenuates it.

Of course, it is not all clear sailing from here. There exist some plausible alternative explanations of the results of the first two experiments, and one of the most compelling of these is examined in Experiment 3.

Experiment 3: General (Nonspecific) Activation or Motivation Effects

A reasonable alternative explanation to the startling findings of Heckhausen's research group is that interrupting a task causes a general, nonspecific, increase in motivation. Such activation would produce effects similar to those found in the first two experiments, independent of the motivational/volitional distinction that is purportedly crucial to the proper understanding of human cognitive functioning.

To test this possibility, the researchers reasoned that enhanced general activation would be especially evident in situations involving highly overlearned tasks – e.g., simple arithmetic problems – where working memory would be most heavily implicated. However, variations in working memory capacity would not be expected to vary as a consequence of decisional status. Accordingly, Heckhausen and his colleagues performed a study in which subjects in a pre- or postdecisional state of mind were asked to solve a set of simple arithmetic problems. In general design, this study, Experiment 3, mimicked that of Experiment 2.

As before, baseline data were collected. Then, subjects were asked to work on a decision; half the subjects were tested before they were allowed to make the decision, the others immediately afterwards. The critical dependent measure in this study was the number of simple arithmetic problems the subjects in the different experimental conditions solved in a limited period of time. As will be seen, the results supported Heckhausen's motivational model along with his interpretation of the first two studies, and rendered implausible the general, nonspecific activation hypothesis:

- Analysis disclosed no initial (baseline) differences between the two groups.
- And, there were no differences between the pre- and postdecisional groups in posttest performance.

This pattern of results suggests that general, nonspecific motivation cannot reasonably be viewed as responsible for the superior performance of the motivational subjects of Experiments 1 and 2. Of course, it is hazardous to base much on a null result; in combination with the first two experiments, however, and in light of the competing predictions derived from the motivational and the nonspecific activation hypotheses, the results of Experiment 3 can be viewed as clearly supportive of Heckhausen's Rubicon model. They provide no evidence in favor of the nonspecific motivation explanation.

Experiment 4: Central and Incidental Memory

The findings of Experiment 2 on the influence of mental set on short-term memory are very important. If these results are replicated and confirmed, they will have both theoretical and practical implications for approaches to teaching, training, and learning. However, for Heckhausen's theory, the data pose an interesting question. The theory is formed on the explicit expectation that people in whom a motivational mental set has been established will be more open to information, more likely to see the broad picture – in short, will exhibit a broader breadth of attention to the stimulus field in their attempt to solve the problem confronting them. This conceptualization does allow for the (successful) prediction of the central memory differences obtained in the second experiment; but it is more directly supportive of an expectation for differences in incidental memory, which were not examined in Experiment 2.

Incidental memory is concerned with features of the stimulus field that are not directly the focus of task at hand, but which nonetheless impinge on the individual's attention. For example, most of us have experienced the usually embarrassing encounter in which a friend presents us with a complicated mathematical puzzle, verbally, and at the end asks not the results of our calculations, but some other, completely incidental bit of information that he or she passed on in posing the problem. This is a rough example of the kind of thing that cognitive psychologists do when studying incidental learning. If the Rubicon model operates as Heckhausen has proposed, then incidental as well as central memory processes should be

improved in the motivational mindset conditions, relative to performance of volitional subjects.

To test this possibility, Gollwitzer and Heckhausen (1987) performed a study that was in general design, but not detail, similar to that of the first three experiments presented in this report. Subjects were told that they were going to have to play the role of a personnel director who would have to decide between one of two individuals who were competing for the same job. Before beginning, they completed a test of memory that was apparently unrelated to the judgment task.

Then, subjects were provided (via written material and slides) the information on which to base their judgment. Half were interrupted before making their decision, and given a second memory test. The remaining subjects were allowed to decide, and then were tested.

The second memory test consisted of a series of six slides. Each slide contained a sentence; together, the six slides (sentences) formed a story. Ostensibly, the task was to memorize the sentences verbatim. However, all was not quite so straightforward, for two incidental nouns were attached to each sentence. Placed above the first word of each sentence, and below the last word, were nouns that had nothing whatever to do with the story being learned. They were colored differently from the other words in the sentences (green vs. black), and were chosen so that they were equally and highly familiar to the German-speaking subjects.

At the end of the learning episode, the subjects attempted to recall the sentences exactly as they were presented. Then, they were given a booklet that contained 24 nouns, 12 of which were the incidental nouns that had been presented. Their task was simply to recognize and indicate which of the 12 incidental nouns had appeared (in green) on the slides they had viewed.

As described here, the experiment contained both a central learning task (which was included for the sake of replicating Experiment 2) and an incidental learning task (clearly mandated by theory-based expectations). The results of this study are exceptionally encouraging from the standpoint of the validity of the Rubicon model. The direct learning results clearly replicated the findings of the earlier study:

- There were no differences between subjects in the two experimental conditions on the first memory test, which established a learning baseline against which to compare later performance. This is important and necessary, because it indicates that any subsequent differences that might be found cannot be attributed to preexisting variations in the subject samples.
- As in Experiment 2, subjects in the motivational mindset recalled significantly more of the (central) information presented in the six story-sentences than volitional subjects. This difference was significant even after initial memory differences were taken into account, and adjusted statistically.
- While the replication of earlier results was important, perhaps crucial, the most interesting results have to do with the incidental data. Analysis disclosed that motivational subjects correctly identified significantly more of the incidental nouns than the volitional subjects. As in the analysis of central learning, this difference remained even after initial differences in learning ability had been controlled.
- The superiority of the motivational mindset subjects was not a consequence of their simply checking more of the 24 (incidental) possibilities; analysis of the frequency of incorrect choices disclosed no differences between the motivational and volitional groups.

Some Concluding Observations

The distinction between motivational and volitional mindsets seems to me to offer a means of revitalizing an important area of psychology, motivation, that recently had given clear signs of running out of creative energy. Indeed, to me Heckhausen's idea is so plausible it deserves to be right, even if it isn't. Happily, the data give every indication that he is on the right track.

The importance of Heckhausen's research series for basic theory is difficult to overestimate. In my opinion, this work has the potential to revolutionize research not only in motivation, but in learning theory as well. The practical applications of the motivational-volitional distinction, too, have great potential. It is reasonably clear that this work will occupy the research energies of psychologists for some time to come. The full implications of the Rubicon model have yet to be even thought of, much less explored. Psychology will profit as these explorations proceed.

As yet, there is little published material on Heckhausen's model. However, as time goes by, we can expect to encounter more and more research on motivational versus volitional mind sets in the pages of our experimental, cognitive, and even social psychological journals. I hope that this report has given some insight into this important development, and that it has provided readers with a brief head-start in thinking about, and perhaps even conducting research on, what promises to be a research series that will alter fundamentally the ways we think about thinking.

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7/19/88

COMPUTER SCIENCES

Computer Science at the University of Bremen

by Daniel J. Collins. Dr. Collins was the Liaison Scientist for Aeronautics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He has returned to the Naval Postgraduate School where he is a Professor of Aeronautical Engineering.

Founded in 1971, the University of Bremen is a relatively young university as far as German universities are concerned. My visit to the Computer Science Department and to the Statistics Group, which is also a part of the Fachbereich Mathematik und Informatik, was in part motivated by the fact that it is a young department. The university, numbering about 8000 students, has around 500 students enrolled in computer science. (This number of students might be contrasted with the 2000 or so computer science students in each of the Berlin and Munich universities.) The staff consists of 10 professors and 29 assistants of whom 10 are paid from outside funds. Most of the assistants are probably working for their doctorates. The computer science organization appears to be oriented towards the American departmental organization rather than the German institute structure. A software technology center is planned for the university and this might have an interesting impact on the department.

I will discuss the computer science department first and then the statistics group.

Computer Science Department

My host for my visit to the Computer Science Department (CSD) was Professor H. Kreowski. The research is conducted in the fields of theory of computation, theory of programing, programing languages, data base systems, computer networks, pattern recognition, computer graphics, software engineering, expert systems, and the computer and society and the computer and law. There is a bulletin available from Kreowski which lists the research interests of CSD in detail. For the purposes of this article I would like to highlight only some of the activities.

Theory of Programing. With the purpose of improving programing and minimizing errors, data types are introduced into programing languages. Data types form algebras within the language so it is possible to define operations, sorts, and denote data carriers (Kreowski, 1987). By application of algebraic theory it should then be possible to prove the correctness of a given piece of software and thus ensure the reliability of the final program. This idea is the purpose of the research. The concepts of rule-driven generation of patterns, decidability, and complexity of graphical languages all fit within this framework.

PROSPECTRA. Professor B. Krieg-Bruckner is working on the ESPRIT project PROSPECTRA (program development by specification and transformation) (Krieg-Bruckner, 1988). The projects aim is to develop a rigorous methodology for the development of correct ADA software. The starting point for the correct software is a formal requirements specification. Further development is obtained by stepwise transformation that guarantees a prior correctness so that a validation step is not necessary. The transformation idea has previously been applied only to experimental computer languages. One of the problems with the current approach in PROSPECTRA is its inability to handle scheduling; the present approach is to separate out all scheduling aspects of the program. Four universities in Germany, a university in Scotland, and companies in France, Denmark, and Spain are working on the project.

Statistics Group

Professor H. Kinder indicated that the main research activity in the Statistics Group (three professors and six

assistants) is in areas of applicaiton areas where statistics form an important part of some experiment. The applications require general statistic methods such as linear models, case studies methods, asymptotic methods, and bootstrap methods. What is interesting in the work is not so much the methods, some of which are well known, but the wide application that these methods have in a variety of sciences. Thus, much of the research of the group is done with people from other disciplines. The following paragraph has two examples of the applications areas.

Biological applications extend from the estimation of the growth curve of Krill in Antarctic waters to the study of disturbances in circadian rhythm (Vicker et. al., 1988). In toxicology, current projects include the effect of herbicides on plants, the effect of heavy metals on mutation rates, and a long-range study, which has lasted 15 years, on the effect of smog on a population. In medical applications decisions must be made on which is the better therapy for a sickness given one or more approaches and methods based on previous records designed to improve diagnostics. The list which I was given includes some 21 projects with 20 publications that the Statistics Group is now working on. The diversity of the groups's work and interest I found in it have changed my ideas about statistics.

Conclusions

The computer science department is a young, active department with special interest in the development of methods which ensure correct software. The results of the ESPRIT project should be particularly interesting since these project are designed to lead to a commercial project. The applied research of the statistics group is interesting in its very breath.

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8/11/88

Parallel Computing at Santiago

by Paul Roman. Dr. Roman was the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office from September 1984 to September 1988.

The Computer Science Division at the ancient but recently most successfully modernized University of Santiago de Compostela in Northwestern Spain belongs (somewhat surprisingly, but, in my opinion, quite rightly) to the Faculty of Physical Sciences. It has eight faculty members of professional status, and produces about two Ph.D.'s per year. The research activities are organized along two main streams: artifical intelligence and parallel computing. The first activity has been described in a longer article (*ESNIB* 88-08:20-23[1988]); this note is concerned with the second area of research.

The research in parallel computing is directed by a young, sedate, energetic scientist, Professor E. L. Zapata. His main interest, at this time, is the theory of optimization of array processors. In particular, he is concerned with finding parallel algorithms for a hypercube architecture. His major goal is to reduce the number of processors needed for particular classes of tasks.

In one of his very recent projects he describes what he calls the "parallel fuzzy clustering mechanism," which is a parallel algorithm for fuzzy clustering on large data sets. This algorithm makes it possible to handle arbitrary numbers of data points, features, and clusters cost-optimally by hypercube computers of arbitrary cube dimension.

The only limitation is the size of the local memories of the processors. The scheme owes its flexibility to the association of each of the three dimensions of the problem (i.e., number of data points, features, and clusters) with a distinct subset of hypercube dimensions.

In another, as yet unpublished paper Zapata describes the design of a pattern-fuzzy-cluster, using a systolic array. One of the most popular techniques for fuzzy clustering aims to achieve a minimal squared error within the group. But making fuzzy clustering systems practically feasible is hampered by requirements of computer time and storage. Recent advances in very-large-system-integration (VLSI) technology have led to the idea of implementing clustering techniques directly in the hardware. In fact, the extensive vector and matrix calculations involved in minimum variance clustering make systolic architectures especially suited for such applications. Now, Zapata's proposition presents a VLSI systolic architecture for fuzzy clustering. It is based on elemental mo-

dules. The modularity and the regularity of the proposed architecture make it suitable for VLSI implementation. Zapata demonstrated that the total processing time for each pass of membership-function and cluster-center-updating is, essentially, dominated by the time required to fetch the cluster center matrix once.

Although I am surely not competent in this field, I think that the Santiago parallel computing group's work deserves careful attention.

8/11/88

CONTROL SYSTEMS

Controls Research in Switzerland

by Daniel J. Collins. Dr. Collins was the Liaison Scientist for Aeronautics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He has returned to the Naval Postgraduate School where he is a Professor of Aeronautical Engineering.

Research in control theory in Switzerland is centered at the Swiss Federal Institute of Technology (ETH) in Zurich and at the Polytechnic School in Lausanne (EPFL), which has a student body of about 3000 – about one-fourth the enrollment of ETH. I will begin the discussion with a review of the work at the ETH followed by a discussion of work at EPFL.

Swiss Federal Institute of Technology

My visit to ETH was limited to the Department of Automatic Control, which is responsible for the teaching of control theory in the School of Electrical Engineering. My host for the visit was Professor M. Mansour. The professional teaching and research staff numbers 32; six students are presently pursuing the doctorate degree. The two full professors in the department are Mansour and W. Schaufelberger. Research in the Department of Automatic Control has three major directions: theory, computer control, and computer aided design of control systems.

Theory. In the theoretical investigations the major emphasis is in two areas, that of robust control and that of identification and adaptive control. Mansour has recently reported on the necessary and sufficient conditions for the stability of discrete systems with parameters in a certain domain of the parameter space (Mansour, Kraus, 1987). Typically one would expect that all corners of the polyhedron would be needed to insure stability analog to the weak Kharitonov theorem. It is shown however that the robust stability of Schur polynomials depends only on a relatively small number of corners, which is analog to the strong Kharitonov theorem. Further work in this area has been the development of a new synthesis method for designing H^{∞} controllers. The excess stability margin is optimized under the requirement that all closed-loop poles be located left of the j-ω axis a given distance, d, with the result that asymptotic regulation and disturbance rejection is ensured for the class of perturbation that does not exceed the excess stability margin. Another advantage is that there are no constraints on the poles and zeros of the plant with this method.

In identification, methods of parameter estimation are being investigated. In particular, the department is studying a new approach involving parameter-weighted least squares fitting which permits minimization of an estimate of the relative error. Both direct fitting and recursive fitting are being considered. In the case of adaptive control, emphasis is on control of systems in which there are large state and parameter variations.

There are a variety of applications for the theoretical studies. An experimental program which is ideal for the study of robust controllers is being conducted on a double inverse pendulum. This experiment is also being used to study strategies of transferring a nonlinear system from one equilibrium point to another. For a simple inverted pendulum the system works quite well. Work is just beginning on the double pendulum, which is a rather more difficult problem. Although this experiment may seem academic, the ideas involved have direct application to robotic motion and, perhaps as a result, the department has a cooperative program in robotics with IBM.

Large power systems are being analyzed with respect to online stability, identification, and adaptive control. The power system involves the concepts of decentralized control and of hierarchical control. Finally, the department is doing work in the modeling with robust and adaptive controllers of heating and air-conditioning systems.

Computer Control. The emphasis in this area is on the development of real-time software. Real-time soft-

ware involves a whole series of concepts which have particular application to process control. Normally a model-following system is used which emulates, perhaps, a rather complex and nonlinear process. This modeling, if it is to be an effective part of a process control system, must be in real time so that operators of the system can effect timely changes or, indeed, insure in some cases the integrity of the system. A physical model of a power network system has been developed in the department, and computer solutions to control problems under real-time conditions are being analyzed on this model.

Computer Aided Control System Design. One of the strong points of the Department of Automatic Control is in computer aided control system design (CACSD). Dr. C. Rimvall, who did his doctoral dissertation (1986) at ETH, gave me a demonstration of the CACSD computer package with what I thought somewhat impressive results. The system is based on the computer code IMPACT, which is a computer aided design (CAD) code designed to serve both the inexperienced user and the expert control designer. A menu-driven system permits the novice to access complex control system algorithms with a minimum of help. For the expert there is a full-fledged structure command language with many of the elements of a higher computer language. Several data structures are supported for state space or frequency domain representation of high-order systems with nonlinearities. Impact is written in ADA and has interfaces to control algorithms written in Fortran. Since CACSD involves many different control algorithms and control methods, the system is being supplied with an expert system (artificial intelligence).

There are several other activities in the department which I have chosen only to list. These include other software programs used in teaching, modeling and control of biological system, and pattern recognition and analysis of transportation systems. Further information on these activities and others not mentioned are available through a departmental report which can be obtained from Professor Mansour.

Ecole Polytechnique Federale de Lausanne

The Control Institute at EPFL is directed by Professor R. Longchamp. The professional staff numbers about 18 with six students pursuing their doctorates. Much of the research in the institute is project-oriented for specific industrial applications. This industrial work supports about 50 percent of the staff. More theoretical investigation are in the area of robust and adaptive control and in computer aided design systems for control (CAO). I shall discuss some of the more interesting projects and then comment on the theoretical work.

Projects. One of the more interesting projects is concerned with air-to-air interception by a missile. In this project the guidance and control of a modern air-air missile based upon linear programing and upon sliding mode control is considered. The use of a sliding mode controller is the most interesting idea of the project. Some reduced dimensional analysis is also included. The control system appears to be very effective in multiple engagements. Unfortunately, publications are not available on the project.

One of the strong points of the institute is the use of numerical control in manufacturing equipment. A complete test bed with hydraulic actuators on a machine lathe has been developed in the laboratory to test control algorithms. A new command system for two-dimensional machine contouring has been developed on this test bed. The feedback signal (position of tool) is used in identification and adjustment of the parameters of the system which is part of the adaptive controller. This information is used in a feedback loop whose output signal is proportional to the estimation of the perturbations in the system. In addition, there is a feedforward loop and a regular control loop. The test bed has been instrumented, and software is available to permit the comparison of different control strategies (Hulliger and Longchamp, 1987). The adaptive control algorithm is clearly superior to other algorithms in minimizing the displacement error of the tool. A similar numerical control approach to the rotation of a cement kiln has resulted in considerable energy savings. The controller is adaptive and hierarchical in nature and causes the process to be more continuous, with the resulting energy saving.

Theory. The institute has a strong effort in adaptive control algorithms as can be seen from the project discussion. The development of on-line identification algorithms complements or is indeed necessary for the adaptive algorithms work. The identification algorithms are based on recursive least square methods. Polynomial methods are used in the command law in the identification algorithms in order to decrease computational complexity and obtain real-time control.

In the area of robust and adaptive control the main effort has been on the use of a sliding mode controller to handle conditions in which there are errors in the control signal and in the modeling of the system. Simulation has shown that an adaptive and robust system – not only for static model errors but also for time varying modeling errors – results from the application of the sliding mode controller. Thus this method of analysis is applicable to reconfiguration algorithms.

Finally, in the area of computer aided design for control systems an effort is being made to develop a computer code for the use at the institute. I believe this work is just starting.

Conclusion

A larger effort in controls is taking place at ETH than at EPFL. This is clearly due to the difference in size of the two universities. ETH has completed some significant theoretical work in the area of robust control. Computer aided design of control systems is also a very strong point in the control department at ETH. The work at ECFP shows some excellent applications of control theory to industrial problems. The institute also appears to have developed a very effective adaptive control algorithm for numerical control of machines. My conclusion is that the controls work in Switzerland is of high order in both fundamental and applied research.

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8/11/88

The Pearl Program and Process Control at the University of Hannover

by Daniel J. Collins.

The Control Institute of the University of Hannover in West Germany is directed by Professor M. Thoma, who is past president of the International Federation of Automatic Control (IFAC). Among many other activities Thoma is also general editor of Springer Verlag's *Lecture Notes in Control and Information Sciences* series.

The research staff of the Control Institute numbers around 23, and typically, five of the staff obtain their doctoral degrees each year. The main research effort of the institute is the modeling and control of biological and chemical processes. Process control can be exceedingly complicated and involve multitasking, hierachical control, real-time programing, nonlinear control systems, and data base handling. Indeed these complications form the basic elements of the research program at the institute. Just as a good nomenclature can make certain mathematical problems simple, a good software language can structure and facilitate solutions to process control problems. A unifying theme at the institute is the use of the language PEARL (Process and Experiment Automation Real-Time Language) as a vehicle for the study of multiprocessor and real-time systems and as the programing language used in the development of control systems.

PEARL was developed by Professor W. Gerth of the institute about 7 years ago. The language has met with some success in West Germany and is now commercially distributed. The language structure includes real-time commands, multitasking, abstract data types, and a modular construction. One of the important features of the language is the ability to specify the hardware configuration. Thus the language is suitable for distributed processor systems and hierarchical systems. More significant is the possibility to reconfigure the systems through the software – i.e., PEARL. Several other features of the language are specifically directed at process control.

At the University of Hannover's computer center PEARL is used in conjunction with RTOS, a real-time operating system also developed by staff of the control institute. The institute's more recent work has been the development of a real-time data base processor using RTOS/PEARL. As can be seen, one of the continuing activities of the institute is software development of PEARL, of real-time operating systems, and of multiprocessor systems. One aspect of this activity has been the extension of the PEARL language to microcomputers. With respect to hardware implementation of some of the software concepts it is interesting to note that the institute has developed its own computers and cards in the past. Multiprocessor computers based on the chip 68000 are now being developed for process control.

Research in the biological and chemical processing area is fairly specific in that it is concerned with an immediate industrial process. In single-cell protein processes there are three aspects of the problem: mathematical modeling, parameter identification, and adaptive control. Thoma has investigated biological growth processes in vats and in tower loop bioreactors. A current example of this work is the modeling of the dynamics of the growth and production of *penicillium chrysogenum* undergoing both quiescent growth in a bioreactor and aeration of the fermentation broth. When one realizes that over 12,000 tons of penicillin is produced a year,

the importance of the process becomes evident. Since much of the work in this area is company-specific it is of a proprietary nature.

In order to reduce the complexity of large-scale systems, decentralized controller and hierarchically composed subsystems are introduced in the modeling. There can be two aspects of the decomposition – one called multilayer systems, in which the control of the system is divided into layers which operate at different times, and the other, called multilevel systems, where the control actions of lower levels are coordinated by processors at higher levels in a hierarchical manner. Current work is on concepts in two-level hierarchical systems involving decentralized observers with model reduction concepts used to reduce the number of states of the system.

Two rather elegant experimental examples of nonlinear controllers which have been developed in the laboratory are contained in an inverted pendulum system and a model railroad system. The classical inverted pendulum problem is to balance an inverted pendulum over a given position on a moving car. Normally the car is confined to a track which is also the plane of the pendulum motion. The track is positioned at a level which permits the pendulum to hang in the down position without touching the floor. There are then two aspects of the problem: first, starting from the down position, to invert the pendulum (up position) and once it is in the up position to, second, stabilize the motion over a given point on the track. The stabilization part is fairly easy since it involves small displacement, and one can use a linear controller. The inversion part is difficult since the motion is nonlinear. In the institute's setup the PEARL language is used to switch from the linear to the nonlinear controller. Another distinguishing feature of the system from several other inverted pendulums that I have seen is the use of an observer to obtain the pendulum inclination angle. Work is now directed to a nontrivial extension of the experiment to a double inverted pendulum. This latter work is part of a doctoral thesis.

The nonlinear railroad system consists of two trains on a double track system which has a single track over which both trains must travel in the opposite direction as they traverse the system. One train is considered to be the fast train with a fixed time schedule which should not be delayed by the slow train, which may be sidetracked at given locations. The problem is: given any initial position of the two trains and the given track layout, develop a control strategy that insures the proper scheduling of the trains. The train positions and velocity are sensed at given track locations. The controller can vary the velocity and positions of the trains. Time optimal and energy optimal solution have been obtained for this problem with implementation in the PEARL language and with the help of spline function. I believe this is the first time a problem such as this has been solved completely.

Conclusions

The software developments of the University of Hannover's Control Institute greatly facilitate the resolution of the research problems considered by the staff. Some very applied work is coupled with fundamental investigation of multilevel and nonlinear systems. The experience of the staff is ideally suited to the the development of multiprocessor and real-time systems. One of the strong points of the center is in process control of chemical and biological systems.

7/25/88

ELECTRONICS

The 5th International Conference on Semi-Insulating III-V Materials

by Howard Lessoff and Wen Tseng. Drs. Lessoff and Tseng are both from the Electronics Science and Technology Division of the Naval Research Laboratory, Washington, D.C.

Introduction

As the III-V semiconductors play an increasing role in electronic and optoelectronic technology, the need for stable and uniform semi-insulating (SI) layers and substrates becomes a key issue. This meeting, the 5th Conference of the series, had as its main emphasis the preparation and characterization of III-V SI materials. The location of the 5th International Conference was at the Old Town Hall in Malmo, Sweden, on 1 through 3 June

1988. There were two receptions, one held in Malmo and the other at the historical and beautiful University of Lund. The conference was attended by 186 scientists from 20 different countries. The meeting consisted of seven sessions including a rump session on Thursday evening 2 June. There was a total of 14 invited and 94 contributed papers. The meeting technique used was a combination of invited talks, posted papers and general discussion.

There were no simultaneous sessions so that all the attendees could be at all the presentations. Each session started with one or two invited papers followed by a time set aside for reading the various contributed papers that were posted on bulletin boards. This was then followed by a discussion period, via questions and answers, of the posted papers. The procedure did lead to improved discussions of the papers when they were being read since an author was expected to be available at his poster. But it did not lead to general discussion for there was a tendency for the participants to read only those papers in which they had a direct interest.

The session consisted of the following subjects: defect dynamics, epitaxy with applications, bulk growth, compensation and characterization, transition metals and point defect identifications, mapping, and the rump session on what was needed to insert gallium arsenide (GaAs) into current system applications. Because of the large number of papers presented it will not be practical to discuss each but rather to hit upon some of the highlights of the meeting. This selection will admittedly be biased based upon our personal interests. The conference proceedings are scheduled to be published in late 1988 or early 1989.

Defects in Semi-Insulating Material

In the defect session, D.C. Look (Wright State University, Dayton, Ohio) presented an overview of annealing, and the creation and reduction of the native defects, especially EL2 concentration. D. Hurle of the UK's Royal Signals and Radar Establishment (RSRE) discussed native defects as related to the control of crystal growth and the stoichiometry of the melt. A considerable number of papers were presented on the influence of annealing on defects, both native and extrinsic. A number of investigators attempted to relate or project device uniformity to a number of parameters including: (1) the SI wafer resistivity, (2) EL2 concentration and distribution in the substrate, and (3) the presence of excess arsenic in the melt during crystal growth. Y. Kitagawara (Shin-Etsu Handotai Co., Ltd., Japan) reported the presence of arsenic precipitates approximately 100Å in size, in crystals grown with excess arsenic. He also discussed the nonuniformity of GaAs boules from the seed to tail being due to the thermal history of the boule during growth. Using ion implantation, P. Suchet (Laboratoire d'Elect et de Physic Appliquée, France [LEP]), reported the stability of post-annealed substrates. Although substrates from various venders and boules appear very uniform and homogeneous prior to implantation, after implantation some of the substrates appeared quite nonhomogeneous and were not suitable for devices.

Compensation and Characterization of Defects

This defects session raised perhaps more questions than were answered. It is apparent that there is limited knowledge as to what are the dominant shallow acceptors in SI GaAs. Among the suggested shallow acceptors, carbon has been considered to be the dominant impurity and was part of the 3-level model to achieve SI GaAs. L. Sargent (University of Oregon Graduate Center) presented data that indicate the formation of undoped SI GaAs that is nearly carbon free. There was a lot of discussion as to whether the current models are adequate to explain the SI behavior of GaAs, especially in light of measurements of the carbon content. The role that carbon plays in SI GaAs is not understood – a number of papers presenting differing conclusions. According to E. Weber and M. Kaminska (University of California, Berkeley), positron annihilation experiments have demonstrated the existence of large concentrations of vacancy-related defects which have not yet been electrically characterized. K. Chino (Sumitomo Metals Mining Company, Ltd.) said that Sumitomo has grown undoped SI GaP using the liquid encapsulated Czochralski (LEC) process with PBN crucibles, and that there appears to be a native deep donor phosphorus on a gallium site which plays a significant role in the SI properties.

Epitaxy and Applications

R.Y. Koyama (TriQuint Semiconductor, Beaverton, Oregon) pointed out in an invited paper the need for major improvements in material and device processing if the promise of III-V semiconductors for integrated circuits is to be achieved. Among the parasitic effects that need addressing are low-frequency noise, transients, radiation tolerance, and especially "backgating" as experienced via the nonuniformity of the pinch-off voltage in field effect transistors (FET's). Which of the problems are related to processing and which are related to the material technology has not yet been resolved. Among the techniques discussed to reduce the backgating were use of shielding structures, proton implantations, and guard rings. The variation in EL2 could not be correlated with variation of carbon concentration in the SI GaAs. (This also further expanded the carbon discussion in the previous session.)

A number of papers on SI InP layers grown via transition metal doping were presented. The implied increase in the use of InP is directly related to applications of fiber optics at the longer wavelengths where optical fibers have lower losses. S. Yamakoshi (Fujitsui Laboratories, Atsugi, Japan) presented an interesting method of achieving SI epitaxial layers followed by the growth of an active layer for both InP and GaAs. The procedure involves the growth of a transition metal-doped layer of the III-V material via chloride VPE. The VPE-grown Fe-doped InP layers on InP exhibited resistivity as high as 10^{-8} ohms-cm. After the high resistivity layer is grown, the active layer is produced at lower temperatures via organo-metallic chemical vapor deposition (OMCVD). The use of lower temperatures is essential to prevent the diffusion of the transition metal into the active layer. The technique is considered applicable for the growth of lasers, and already an embedded laser diode has been prepared with a frequency response of better than 10 GHz. A.C. Carter (Plessey, Coswell Towcester, UK) discussed the material needs for integrated optoelectronics. The materials systems Carter stressed were those based on InP because of the long-wavelength potential. The candidate material systems are AlInAs/GaInAs for metal shottby FET's (MESFET's), GaInAs for JFET's, and InP based for HBT's. In the long term, if the method of growing stable strained layer devices proves feasible; then GaAs on Si, and In-based materials on GaAs of Si could be possible. Currently the integrated optoelectronic devices properties are inferior to discrete components, and the yield of the integrated devices is low.

The DX center was discussed by a number of researchers with special emphasis on the serious problems the center has on modulation FET's (MODFET's) or HEMT's but not on lasers. The problem of variation of the threshold of ion-implanted MESFET's into SI substrates has been blamed on variations in EL2 and on defect density as exhibited by etch pits; Y. Fujisaki (Hitachi Corporation, Kokubonji, Tokyo, Japan) presented data that indicates striations or nonuniform stoichiometry results in inhomogeneous activation of implanted Si atoms in defect free In-doped SI substrates. Long-term annealing of undoped SI GaAs did improve the uniformity of implanted devices but for In-doped SI GaAs, the striation effect did not improve with annealing.

Transition Metals and Point Defect Identification

As usual for a meeting where SI III-V materials are discussed there was the normal amount of papers concerning EL2 and a host of other mid-gap levels – and hypotheses as to their origin. There seems to be no consensus of opinion. Experiments have been preformed by a number of laboratories in doping the III-V semiconductors with many impurities including: Fe, Ta, Nb, V, Cd, Be, Cu, Mn, Ti, Ta, W, Nb, Au, Cr, Cd, and Zn; as well as a large amount of work on isoelectronic doping for impurity hardening. The uses of the various mid-gap levels are attempts to achieve SI properties and to maintain the properties during device processing. In many cases this has meant lowering the yields per boule since very few dopants have distribution coefficients of unity. By lowering the dislocation density, B. Clerjaud (Laboratoire d'Optique de la Matière Condensée) reports that the stability iron doped InP has been improved. The dislocation density was reduced by isoelectronic doping with Ga at about $10^{19}/cm^3$.

Bulk Growth

The bulk growth session included papers on the growth of materials as well as the characterization. Many of the characterization papers were concerned with gross types of defects such as precipitates and etch pits. It was pointed out that a great deal of GaAs bulk crystals are grown from the arsenic-rich melts which in turn can lead to excess arsenic in the crystal and to arsenic clustering and precipitation. K. Terashima (Toshiba, Kawasaki, Japan) found no direct correlation between epitaxial phase deposition (EPD) and bias voltage or resistivity but did find correlation with crystal composition and impurities such as boron and carbon.

There were two papers on the vertical gradient freeze method for the growth of InP and GaAs at AT&T Laboratories. For both GaAs and InP crystals, the gradient freeze method when compared to the LEC process appears to be capable of reducing the EPD for the same diameter crystals by about 1 to 2 orders of magnitude. There were a number of papers that discussed the effect of the thermal conditions during growth on the properties of the resultant crystals including EL2, EPD, and impurity distribution. It was demonstrated by Hofmann (University Erlangen-Nurnberg, West Germany) that the effective segregation coefficient of impurities and dopants can be changed by the application of a uniform magnetic field during growth. J. Weher (Centre d'Electronique de Montpellier, France) via laser scanning microtomography showed that there are substantial microprecipitates in GaAs and especially In-doped GaAs. J.P. Fillard (also from Centre d'Electronique de Montpellier) found the microprecipitates in the matrix, especially concentrated along dislocations.

Mapping

This session was devoted to methods of characterizing wafers and crystals, including EL2, residual impurities, resistivity, EPD, and dopants, as well as correlation to device application. The group at LEP in

studying both In-doped and undoped GaAs wafers for device applications concluded that both types of materials with proper selection and treatment gave equivalent results in large-scale integration (LSI) circuits. H.Ch. Alt (Siemens, Munich, West Germany) showed that the cellular variations of EL2 do influence resistivity, activation of Si implants, and threshold voltage in FET's. The higher the EL2 concentration the higher the Si implant activation. There were a number of papers on methods of wafer mapping, especially by using luminescence techniques.

General Discussion Session

During the evening discussion session, J.S. Escher (Motorola, Phoenix, Arizona) gave an invited talk on whether GaAs technology will make an impact on actual usage in electronics. He stressed the need for an understanding of what is needed for the electronic designer and device user to use a new technology. Among the items discussed were process control, standards, yield, reproducibility, costs, and interactions between the vendors and the users.

Conclusions

The meeting brought together a large number of scientists concerned with the growth, characterization, and use of SI III-V materials with emphasis on GaAs and InP. There is an increasing number of papers on the characterization from the basic point of view with a decreasing emphasis on the growth and the use of the material. This can be due to the maturity of the field and the fact that there is greater industrial application of the material; thus there will be less disclosure of potentially important industrial processes. It is quite apparent that increased coordination between the material supplier, the device maker, and the end user will be required if major applications of III-V devices and circuits are to be achieved.

10/11/88

INFORMATION SCIENCES

The Machine-Learning Project of Siemens

by Paul Roman. Dr. Roman was the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office from September 1984 to September 1988.

The Foundations of Information-technology Division of the central research laboratories of Siemens (Neuperlach, near Munich, West Germany) is in the midst of a major 5-year artificial intelligence (AI) project called "Machine Learning" (Maschinelles Lernen, [ML]). This project has two different approaches:

1. Learning within the framework of traditional AI, as a means for improving and extending already existing knowledge-bases by adding to it new knowledge learned from its own applications to concrete problems.

2. Learning in connectionist systems which function as interfaces between the natural environment and a computer.

Correspondingly, current research deals partly with traditionally oriented symbolic learning paradigms; and also with connectionist schemes, massively parallel architectures, and neural networks. The second line of research is strongly emphasized.

Not surprisingly, the huge program originated in the US, due to a longstanding cooperation of Siemens AG, Princeton, on one hand and the Research and Technology Laboratories, also in Princeton, on the other. This cooperation utilized, in addition, well-known academic centers in the US. There are now new cooperative efforts underway, especially with MIT. However, since the end of 1986, the center of gravity of the Siemens AI research moved to Munich. The work in these central research laboratories involves also joint projects and contracting with a number of German universities and industrial firms in electronics. Moreover, the project is coordinated with the all-European ESPRIT-effort aimed at building, within the next few years, a prototype workstation for neural networks.

Neural Networks

The most interesting parts of the Siemens in-house ML research are concerned precisely with neural networks. There are four major efforts in this field, to be briefly described below.

Basic Research in Neural Networks. Better understanding and improvement of already known learning mechanisms and learning methodology, as well as discovery of new network structure is the primary goal here. In the historically proven Germanic approach, the project-leaders emphasize that neural networks may become relevant to practical applications only if one gains a really deep understanding of how neural networks function.

Interfacing of Neural Networks With Other Architectures. The scientists responsible for the ML project believe that neural networks will not be able to solve all possible problems of interest. Thus, it will be necessary to continue relying on von-Neumann architectures, traditional software technology, and classic AI. Hence, to utilize neural networks in such an environment, it is imperative to develop interfaces with these techniques. A synergetic development approach of ML and other technologies, is a serious research topic.

Development Tools for Neural Networks. It becomes more and more necessary to develop training-environments for neural networks which not only facilitate good ML, but also allow for optimizing the networks in relation to specific requirements. The Siemens ML project plans to build within the next 2 to 4 years several versions of developing-environments and training-environments. To begin with, these will be relatively simple systems permitting the choice of a suitable structure, of layers, and of learning algorithms. The more sophisticated versions, to be developed later on, will also provide testing environments in addition to synthetic functions and to generating task activities.

Validation of Procedures. It is necessary to ensure that the insights gained in the course of basic explorations be truly relevant for later nontrivial applications. The Siemens researchers decided to make use of the world-renowned SPICOS project (Siemens-Philips-IPO Continuous Speech Understanding System) for the purpose of objectively validating partial results in the neural network research. (SPICOS is an integrated system which takes natural language input, processes it as needed, uses the result to query databases or knowledge bases, and then synthesizes the answer in natural language.) Now, in the validation procedure, selected parts or components of SPICOS are replaced by alternative neural networks. Thus, comparison of the conventional and neural-net solution inside a sophisticated environment can objectively be achieved and judged. Other validation procedures will use problems in image-processing.

Hardware Considerations

At this point, the attentive reader may ask: "What about hardware?" In this area, the Siemens project-directors also adopted a cautious approach. First they note that, for the foreseeable future, existing, well-proven, and selected task-specific hardware is fully adequate for performing the high-level research tasks. Second, the scientists do not want to commit themselves to any specific hardware design or architecture before a fully optimized arrangement emerges from long, broadbased, basic research. Once understanding of neural net functioning and of ML is really well accomplished, the ideal chips can be, no doubt, quickly produced. The scientists proudly add that this confidence is based on recent Siemens successes in the use of CAD for VLSI tasks.

Achievements and Plans

The areas in which Siemens' AI research in general, and ML studies in particular, proved so far most successful, are speech recognition and pattern-recognition/machine-vision. (A third area, not within the scope of this article, is industrial expert systems. With their offering of over 40 systems, Siemens appears to be the largest European – possibly worldwide – producer of expert systems.)

In the field of speech recognition, issues related to real-time recognition and to recognition under nonideal circumstances are central endeavors. Effective use of perceptual knowledge and of knowledge-based and learning techniques leads to good progress at the acoustic-phonetic level. Neural networks appear to be particularly promising. Expertise has been achieved in speaker-verification, speaker-independence, speaker-adaptivity, and connected word recognition for small vocabularies.

In the field of *pattern recognition,* one activity concerns sensor fusion tasks, primarily for improving machine vision and robotic applications. Another focal point is transmission of moving images. Using AI methods (and especially ML) for image processing and image recognition, substantial success was achieved in transmitting in almost-real-time the images of moderately fast moving scenes on the standard, simple, inexpensive 64 Kbit/sec ISDN lines.

Regarding more general plans in the area of ML, the researchers follow two major approaches:

- Symbolic concept formation
- Connectionist models.

The first of these can be further divided into empirical learning and *explanation-based learning* (EBL). Currently, the focus is on the latter approach, which uses a theorem-prover and encoded knowledge about the world to interpret events; this approach has an unprecedented potential for autonomously increasing the system's store of knowledge. Siemens is now developing EBL systems that reason about several problems at once, and thus aim at a consensus. Another system under development analyzes its mistakes as it attempts to solve a problem, so that it can avoid similar mistakes in the future.

Regarding work on connectionist models, nothing can be added at this time to what we already described in the earlier part of this article.

Concluding Remarks

It would be certainly profitable for US specialists in AI to closely follow developments in the Siemens ML project. The current contact person is Werner Remmele, Siemens AG, ZTI INF3, Otto Hahn Ring 6, D-8 München 83, West Germany. Telephone: (011-49-89) 636-44237. I would appreciate receiving copies of any correspondence.

8/11/88

OCEAN SCIENCES

Mathematical Modeling of Sediment Transport in the Coastal Zone–a Hydraulic Research Symposium

by Jack W. DeVries. Mr. DeVries is with the Seafloor Engineering Division of the Naval Civil Engineering Laboratory, Port Hueneme, California.

The International Association of Hydraulic Research sponsored a symposium entitled, "Mathematical Modeling of Sediment Transport in the Coastal Zone" in May of 1988. The symposium, which was held in Copenhagen, Denmark, was organized by the Danish Hydraulics Institute; it was attended by both researchers and consulting engineers who represented some 20 countries from around the world. Topics discussed ranged from field measurements of shingle transport to the problems of numerical diffusion associated with a variable finite difference mesh. Despite this broad range of topics, two areas of interest were prominent: cross-shore sediment transport and wave/current interactions. In the following paragraphs these two groups of papers will be addressed along with a few of the most interesting of the miscellaneous papers.

Cross-Shore Sediment Transport

Up until a few years ago, long-shore sediment transport was the surfzone phenomenon that monopolized the interest of coastal researchers. Lately that trend has been changing. Current research, as represented at this symposium, is taking a long look at the cross-shore component of sediment transport.

One of the main difficulties in predicting cross-shore sediment transport is that the integrated cross-shore flow is zero. The transport of sediment is accomplished by a secondary circulation generated by the vertical asymmetry of the wave-induced radiation stress. Rolf Diegaard (Danish Hydraulics Institute, Denmark) has developed a two-dimensional time-stepping routine that addresses this issue. It couples the turbulent energy flux generated by wave breaking with the energy dissipation within the wave boundary layer to develop a vertical velocity profile for the inner surfzone. This velocity profile is combined with a basic suspended sediment concentration distribution equation to predict the cross-shore mass flux.

This approach is similar in many ways to that presented by Bailard (1981) in which the offshore-directed transport imposed by a combination of the downslope component of gravity and the time-averaged undertow is balanced by the onshore-directed transport imposed by the asymmetry of the wave orbital velocity field.

A number of papers presented at the symposium discussed the Bailard equation. The most interesting of these was presented by Bano Roelvink (Delft Hydraulics, the Netherlands). He conducted a series of large-scale laboratory experiments that isolated the various mechanisms employed in the Bailard equation. These experiments addressed three situations: an underwater sand dam with steep slopes on the shoreface where transport is dominated by slope effects; a long, horizontal stretch of sand in the shoaling region of the upper shoreface, where wave asymmetry is dominant; and a steep ramp in the area of initial breaking, where undertow is dominant. Roelvink's conclusions suggest that the Bailard equation adequately predicted the mean cross-shore current, but that in the presence of a bar it is important to consider the time lag between the break point and the initiation of the production of turbulent energy.

Wave/Current Interaction

There were a number of models presented at the conference that addressed the topic of sediment motion driven by a combined velocity field (steady plus oscillatory) generated by waves and currents.

It has been standard practice to account for wave/current interaction in sediment transport by dividing a unidirectional transport formula into stirring and transporting terms. The stirring term, generated mainly by the oscillatory motion, entrains the sediment particles while the transporting term, proportional to the mean current velocity, carries the suspended load downstream. The theoretical basis for this practice was reviewed by R.L. Soulsby (Hydraulics Research, Ltd., UK). He suggests that these formulations can have widely varying results due to their dependence on an ill-defined eddy viscosity distribution. In response, he has developed a general method for deriving a wave-plus-current sediment transport formula from any chosen unidirectional transport formula.

The question of an appropriate eddy viscosity coefficient was further examined by R.R. Simons (University College, London, UK) who critiqued all of the existing formulations.

One of the most interesting papers presented on the topic of wave/current interaction was given by R.A. Beach (University of Washington, Seattle). He has developed a turbulent diffusion model that incorporates an incident wave/long-shore current interaction. It uses a depth-dependent eddy viscosity coefficient. The model was compared with a field data set (which included both velocity and suspended sediment concentration data) collected in the surfzone along the Oregon coast. It was found that the model handled the long-shore suspended sediment flux in a reasonable manner, but that the cross-shore flux could not be modeled using mean velocities or mean suspended sediment concentrations.

Other Papers of Interest

J.P. Hodder, (British Maritime Technology, Ltd., UK) presented a two-dimensional model of Carmarthen Bay, South Wales. The purpose of the model was to define an efficient coastal zone management program for the 70-km-long stretch of coastline within the bay. Tides and deep water waves were modeled using a finite difference scheme. A nested approach was used so that finer detail could be obtained for areas of interest without incurring the overhead expenses associated with using a finer grid.

K.P. Black (Victorian Institute of Marine Sciences, Australia) presented a model describing the sediment transport due to tidal currents within a New Zealand estuary. Due to shell coverings over large portions of the sandy bottom much of the bed was resistant to erosion. The model accommodated this by using a sediment availability function which defined the percentage of seafloor surface area covered by transportable material within each grid cell. A modified bed friction factor was also used to account for the additional roughness of the shells.

A numerical model has been developed by O.H. Anderson (Danish Hydraulics Institute, Denmark) that predicts the morphological changes introduced into a natural system by a man-made structure. The model is designed to operate strictly outside the surfzone. Random waves, currents, bedforms, and sediment transport are taken into consideration in the model, although wave-current coupling is not. Bed level changes are calculated for each finite difference grid cell for each time-step.

Beach nourishment is an environmentally compatible means of coastal protection, but there are many unanswered questions as to where and how the sand should be placed on the beach. H. Oelerich (Leichtweiss-Institute Technical University, West Germany) has developed a two-dimensional model that permits the evaluation of various methods of beach nourishment. The model employs a wave refraction subprogram and an energy dissipation scheme to determine the amount of energy dissipated on the natural beach. Initial results indicate that filling the longshore trough may act as an effective means of beach protection.

Summary

This excellent conference provided an international forum in which the state of the art in numerical modeling of coastal processes was presented. Yet, to me, the discussions held at this symposium emphasized the gulf that still exists between academia and industry. While the discussions serve as an indicator of the problems that are present in the field, at the same time they serve as one of the only tools by which we are presently addressing these problems. Progress is indeed being made throughout the field of coastal sediment processes – in both basic research and the application thereof. The time lag from one to the next is what I find disturbing.

Proceedings from the Symposium on Mathematical Modeling of Sediment Transport in the Coastal Zone are available from the Symposium Secretariat, Danish Hydraulics Institute, Agern Alle 5, DK-2970 Horsholm, Denmark (Telephone: +45 2 86 80 33).

The price requested is DKK350 (about $50) plus postage.

Reference

Bailard, J.A., "An Energetic Total Load Sediment Transport Model for a Plane Sloping Beach," *Journal of Geophysical Research*, Vol. 49 No. C11 (1981), p. 10,983.

10/6/88

Three Major Coastal and Estuarine Engineering Laboratories

by Jack W. DeVries.

I recently visited three of the major laboratories within the international market of coastal and estuarine engineering: Hydraulics Research, Ltd. (in Wallingford, UK), the Danish Hydraulics Institute in Horsholm, and the Delft Hydraulics Laboratory (with offices in Delft and Emmeloord, the Netherlands). Each of these institutions provides consultation and research on contract to both private concerns and governmental agencies. In the following paragraphs the strongest discipline within each organization, as discerned in my view, is described.

Hydraulics Research, Ltd.

Hydraulics Research, Ltd. is one of the leaders in the field of estuarine engineering. (See *ESN* 40-03:112 [1986] for a report on a turbulence meeting at this facility.) Their capabilities include physical and numerical modeling as well as field surveys., Large test tanks are available at Wallingford in which physical scale models of estuaries can be built to scale sizes on the order of 1:70 for large reaches and to 1:30 for smaller reaches. A state-of-the-art computer modeling package is on line that describes two-dimensional sediment motions as well as providing water quality information. A full-time field survey crew that has conducted estruarine surveys worldwide is on board.

Danish Hydraulics Institute

The Danish Hydraulics Institute is very active in the areas of port engineering and coastal structures design. They have extensive physical model facilities dedicated to port and structure work. These facilities all use random, multidirectional wave generators to model the wave climate as well as modeling the tidal fluctuations and the dominant currents. A large three-dimensional basin is available in which models of offshore structures can be tested in a short-crested wave environment. A numerical model is available that describes two-dimensional hydrodynamics in the nearshore area. These include the effects of refraction, diffraction, partial reflection, and brushed ship motions within a harbor. Also available is a numerical model that outputs a time series of significant wave heights and a time-dependent distribution of wave periods and directions based on hindcast data from barometric surface pressure charts.

Delft Hydraulics Laboratory

The Delft Hydraulics Laboratory is a major contributor in the area of coastal sediment processes. (See also *ESN* 40-07:235 [1986] and *ESNIB* 87-01:43 [1987].) A basic research program, funded by the Dutch Ministry of Transport, has been ongoing for 14 years. Through this research, an impressive collection of numerical models describing coastal sediment movements has evolved. Excellent physical modeling facilities also are present. The two most impressive of these facilities are the Delta flume, which can generate random waves up to two meters in height and the oscillatory tunnel, which can model wave periods of up to 10 seconds full scale.

For More Information

Further information on these laboratories can be obtained by request to the following addresses: Hydraulics Research, Ltd., Wallingford, Oxfordshire OX10 8BA, UK; Danish Hydraulics Institute, Agern Alle 5, DK-2970 Horsholm, Denmark; and Delft Hydraulics Laboratory, P.O. Box 152, 8300 AD Emmeloord, the Netherlands.

10/6/88

ONRL-Sponsored Workshop on Modulation of Short Wind Waves in the Gravity-Capillary Range by Non-Uniform Currents

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The Workshop on Modulation of Short Wind Waves in the Gravity-Capillary Range by Non-Uniform Currents was conducted in Bergen aan Zee, the Netherlands, from 24 through 26 May 1988. Conceived and organized by Dr. G. J. Komen of the Royal Netherlands Meteorological Institute (KNMI) and Dr. Gaspar Valenzuela from the Naval Research Laboratory, the workshop was sponsored by ONRL, ONR, and KNMI. Participation was by invitation only, and held to under 30 by design. The objectives of the workshop were to review the field in depth, present new research, and recommend areas for future additional work. By all accounts, the workshop was considered to be a resounding success.

The workshop technical program contained four sessions relating to the theme of the meetings and a discussion session at the conclusion. The first session, Tidal Currents and Bathymetry, was chaired by Dr. Peter de Loor of the Netherland's Central Organization for Applied Scientific Research (TNO) and included informative papers on determining currents over Phelps Bank (D.A. Greenberg, Bedford Institute of Oceanography) and on radar observations of bathymetry in the Netherlands (P. de Loor, TNO). The second session, Electromagnetic Scattering, was chaired by Dr. Komen. Very active discussions took place in regard to the status of electromagnetic scattering models for the ocean surface. There was some consensus that the two-scale model, with Bragg and specular scattering, when properly applied yielded results that were just as good as Dr. D. Holliday's Kirchoff approximation (with one iteration term for the electromagnetic surface fields) when applied to SARSEX data. Three recommendations were agreed upon:

- More quantitative testing of electromagnetic scattering theories for the ocean is needed in well-instrumented wavetanks and ocean field towers.
- A workshop on the mathematical aspects of electromagnetic scattering (theories for the ocean) is desirable.
- More cooperation is needed between national and international interdisciplinary groups to address the problems relating to ocean surface signatures in remote sensing.

Dr. W.A. Oost from KNMI chaired the session on Energy Balance in Short Waves, with Dr. W.J. Plant (NRL) leading the general discussion which followed. From the discussion it seemed clear that further work is needed on realistic expressions for the input from the wind (laminar, turbulent, and two-dimensional), and the dissipation by wave breaking. The source function for the energy transfer by resonant nonlinear interactions seems to be well at hand, except when very short waves interact with very long waves (the two-scale problem).

Professor W. Alpers of Bremen University (West Germany) acted as chairperson for the session on Perturbation of the Gravity-Capillary Wave Spectrum by Current Variation. The Netherland's Dr. Klaartje van Gastel of the Mathematics Institute in Utrecht led the general discussion of the subject at the close of the conference. Various effects are dominant in the separate models of the modulation of short wind waves by nonuniform currents, and, during the discussion, attempts were made to determine which of the effects are necessary to explain the data. This was done by stating for each model its main predictions and the theoretical estimate of the range of validity – i.e., the circumstances under which it can be tested. The outcome of the discussion was that, as they stand, each model can predict striking agreement with some of the data, but for all models, cases exist in which they are inaccurate. A recommendation was made that a unifying theory be developed, encompassing all existing models. This could be achieved by starting anew from the complete energy balance. A further recommendation was that experiments be done to illuminate the role of the physical effects present in the models. The general attitude was that we are quite far along in our understanding of the modulation at L-band, but that the shorter waves still present us with many challenges.

The workshop was considered to be highly successful and it was suggested that a similar meeting would be useful in 2 years' time. Proceedings from the workshop are in preparation, and a limited number of copies may be available from ONRL in the near future.

9/8/88

PHYSICS

The 19th International Conference on the Physics of Semiconductors, in Warsaw

by J.R. Meyer. Dr. Meyer is a research scientist in the Optical Sciences Division of the Naval Research Laboratory, Washington, D.C.

The 19th in the series of bi-annual International Conferences on the Physics of Semiconductors (ICPS) was held from 15 through 19 August 1988 at the Palace of Culture in Warsaw, Poland. Over 400 papers were presented, more than half in the form of posters. Both the number of papers and the attendance (about 800) were slightly less than at the 18th ICPS held in Stockholm in 1986. The conference proceedings will be published by DNH Ltd., the Trade Center of Polish Science. The papers for the proceedings will not be formally refereed, unlike those appearing in previous conference proceedings from the series.

Because of other commitments, I was able to attend only the first 2 days of the 5-day conference. Moreover, since as many as four sessions were scheduled to meet simultaneously, I was able to view personally only a small fraction of the vast amount of new research being presented at the meeting. While I have attempted in this report to focus on perceived trends in semiconductor research at the cutting edge, it is of necessity based on a fragmentary and admittedly biased view of the global picture.

Two presentations from the opening ceremony provided useful encapsulations of the current status of semiconductor physics research. The conference was chaired by R.R. Galazka, of the Polish Academy of Sciences in Warsaw. In his remarks, he emphasized the continuing trend toward reduced dimensionality. While dimensionality is of central importance in virtually all fields of physics, semiconductor physicists have succeeded in making it a tunable parameter. Over the past 10 years, much of the emphasis in semiconductor physics has shifted from bulk three-dimensional systems to the study of two-dimensional systems such as quantum wells. However, only quite recently there has emerged a push toward one-dimensional (quantum wires) even zero-dimensional (quantum dots) systems. Of considerable practical importance is the prospect of new technologies based on these developments, e.g., microstructure devices having a far higher packing density of electronic circuits.

Also speaking in the opening session was the Chairman of the IUPAP Semiconductor Physics Commission, H. Kamimura, of the University of Tokyo. He stressed that by the late 1970's, semiconductor physics appeared to be showing signs of "maturity" as a field, with most of the major problems well understood and only details remaining to be filled in. However, we now find 10 years later that semiconductor physics remains more than ever a challenging field in which the appearance of significant discoveries resulting from highly innovative research is a frequent occurrence. This revitalization from within is evidenced by recently reported progress in such areas as Anderson localization, artificial materials (e.g., superlattices), reduced dimensionality, surface and interface properties, local density and pseudopotential theoretical techniques, and so on. Two of these areas were reviewed in a plenary session which followed the opening ceremony.

Semiconductor Surfaces

D.J. Chadi (Xerox, Palo Alto) gave an excellent review of theoretical progress toward the understanding of semiconductor surfaces. Some of the issues of greatest interest include bonding, stoichiometry, stability, and electronic structure. The body of the talk consisted primarily of a case-by-case discussion of dominant mechanisms governing various surfaces. For example, the (110) surface of GaAs is considered to be the best understood of all semiconductor surfaces. Although the (111) surface of Si is extremely complex, having a 7x7 unit cell structure which contains adatoms, dimers, stacking faults, etc., recent theoretical treatments have finally succeeded in providing a satisfactory description. Other cases such as Ge are less well understood at present, but will probably be unraveled in the near future. Issues requiring further attention include surface structure, surface kinetics, chemisorption, impurities, and defects.

Optical Studies of the Quantum Hall Effect Regime

In another plenary presentation, V.B. Timofeev of the Solid State Physics Institute in Moscow discussed magneto-optical studies of two-dimensional electron gases (2DEG) in both Si MOSFET's (metal oxide semiconductor field effect transistors) and modulation-doped GaAs-AlGaAs heterojunctions. Whereas most experimental studies of the quantum Hall effect (QHE) have been based on electrical characterization techniques, the reviewed work involved spectroscopic studies of electron-hole recombination in the 2DEG at high magnetic fields. The photoluminescence intensity was found to oscillate as a function of transverse field due to filling of the Landau levels. A key feature of the work involved nonlinear screening of the random potential fluctuations. The effectiveness of the screening depends strongly on the filling factor, and it is argued that both the amplitude and the spatial range of the potential fluctuations could be determined from the analysis of the data. If the results and manner of analysis are confirmed to be reliable, they should provide valuable input to theories for the QHE, since free carrier localization is a necessary component.

One-Dimensional Systems

Despite the long-standing US lead in microstructure fabrication technology, much of the most innovative work in the area of one-dimensional systems is currently being performed by researchers from West Germany, the UK, and the Netherlands. Thornton et al. (University of Cambridge, UK) discussed the quantum Hall effect in one dimension, where the one-dimensional channel is defined by electrostatic confinement. The transition from two-dimensional to one-dimensional behavior is observable as the orbit size increases with decreasing magnetic field. Kotthaus et al. (Hamburg University, West Germany) also discussed one-dimensional transport, using 1000-Å-wide GaAs channels made by using a photoresist mask fabricated by means of an optical grating. It was found that a very high degree of uniformity was required if meaningful experimental results were to be obtained. The transition from two-dimensional to one-dimensional behavior was clearly observed in both the infrared optical spectroscopy and magnetoresistance measurements.

Some of the most interesting new results of the conference involved the observation of ballistic transport in one-dimensional structures. In order for a device to be ballistic, there may be no scattering at all between emitter and collector – i.e., the presence of even one ionized impurity in the one-dimensional channel will prevent a signal from being observed. A further unusual feature of ballistic transport is that there is no relation between current and electric field. Results were presented by Wharam et al. (University of Cambridge) as well as in an invited paper by van Wees et al. (Delft University and the Philips company, the Netherlands). The authors predict that, in a manner similar to the quantum Hall effect in two-dimensional structures, the conductance should be quantized in units of $2e^2/h$. The quantized steps are sharply resolved in the experimental data. It is also verified experimentally that in a magnetic field, the width of the steps is altered, but the quantization remains the same. Also impressive is the demonstration by van Wees et al. of "electron focusing," in which an injected electron contributes to the current only if its "skipping orbit" in a magnetic field has the proper radius to strike the collector. It is observed experimentally that the current displays sharp oscillations with magnetic field. A feature of such devices is that their resistivity is extremely sensitive to the field.

Resonant Fe States in Hg-Based Compounds and Alloys

In an invited paper, A. Mycielski of the Polish Academy of Sciences reviewed recent Polish work on HgSe and $HgSe_{1-x}Te_x$ doped with Fe. In HgSe, Fe is resonant in the conduction band, and the electrical properties are extremely sensitive to whether the electron Fermi-level is above or below the Fe level. Whereas the electron density increases linearly with doping level (N_{Fe}) as long as $n < n_c \approx 5x10^{18}$ cm^{-3}, n becomes pinned at n_c whenever the N_{Fe} is greater than that value. At the same time, the slope of the electron mobility vs. N_{Fe} abruptly changes from negative to positive at n_c. The authors argue that when $n > n_c$, the Fe^{2+} and Fe^{3+} ions arrange themselves in a "charge superlattice," similar to Wigner condensation. However, this point remains controversial. They also observe the effects of pressure on n_c. Since the Fe level in HgTe is resonant in the valence band rather than the conduction band, the addition of Te to HgSe should reduce the energy at which the Fermi level becomes pinned. It is clearly demonstrated experimentally that n_c is smaller in $HgSe_{0.95}Te_{0.05}$ than in HgSe.

Band Offsets

A session on band offsets left one with the impression that theoretical estimates of these important heterostructure parameters are still in relatively poor agreement with one another. Most of the theories at least agree that in systems such as GaAs-AlGaAs and HgTe-CdTe, the value for the valence band offset should be fairly large, which is contrary to early estimates of small offsets based on the common anion rule.

Concluding Remarks

My own poster presentation involved the correlation between magnetotransport results and calculated band structures for Hg-based superlattices such as HgTe-CdTe and $Hg_{1-x}Zn_xTe$-CdTe. Although the US has long had a monopoly on the MBE growth of Hg-based heterostructures, private conversations revealed that at least two West German and one Japanese group are planning to begin work in this area. It appeared from the abstract booklet that mine was the only paper at the meeting to deal with either experimental or theoretical work on the HgTe-CdTe system. Despite this, there were a large number of researchers with first- and second-order interest in the topic, and the meeting was more than worthwhile from both a narrow and a global perspective.

10/11/88

The Third International Conference on Scanning Tunneling Microscopy

by Ellen D. Williams. Dr. Williams is an Associate Professor of Physics at the University of Maryland's Department of Physics and Astronomy.

Introduction

The Third International Conference in Scanning Tunneling Microscopy (STM) was held from 4 through 8 July 1988 at the University of Oxford under the auspices of the Royal Microscopical Society. Approximately 300 scientist from Europe, North and South American, Japan, and China attended the conference. The conference was organized in 12 sessions covering the topics of semiconductor surfaces, metal surfaces, molecular imaging, electrochemistry, field emmision, superconductivity, lithography, theory of STM, force microscopy, layered materials and new developments. In the following, a few of the highlights of the conference are reviewed.

Semiconductor and Metal Surfaces

To date, the major concentration of effort in STM has been in traditional (ultrahigh vacuum) surface studies. This was reflected in the quantity and quality of results at the conference. Over 15 different research groups showed high-quality atomic resolution data. While the majority of these groups are at industrial laboratories, a substantial minority ($\sim$25 percent) are now at academic laboratories.

The atomic structure of systems ranging from clean, reconstructed surfaces to surfaces with metal and molecular overlayers was presented. Atomic-resolution imaging of the close-packed Al(111) and Au(111) surfaces was presented, removing any remaining doubts about the applicability of STM to metal as well as semiconductor surfaces. A particular strength of STM was revealed in the imaging of the structures known from low-energy-electron diffraction (LEED) to have large unit cells. STM images revealed the lateral positions of overlayer and substrate atoms within the unit cell, including cases with substitutional or subsurface locations of the adatoms. Such qualitative determinations of the unit cell structure will greatly facilitate analysis of diffraction data for quantitative determination of the atomic positions. In several studies, the STM images revealed the role of antiphase boundaries and two-phase coexistence in the evolution of overlayer structures as a function of coverage. Point defects in periodically ordered structures were also observed. Several groups showed Fourier transforms of their STM data which could be used for comparison with diffraction data from the same surfaces.

Structural measurements regarding the stages of epitaxial growth were also presented. A particularly surprising result was the observation of preferential nucleation at the faulted half of the (7x7) unit cell on Si(111) for both Pd and Cu overlayers. Also observed in various systems were the crystallographic shapes of overlayer "islands," point and line defects in overlayers, and the influence of substrate step structure on the film structure. It is clear that STM will allow a far more detailed understanding of the stages of nucleation and growth than has previously been possible.

In addition to purely structural studies, measurement of the spatially resolved tunneling spectra was performed for several systems. Of particular interest were the use by R.M.Feenstra and P. Martensson (IBM, Yorktown Heights) of this technique to identify the states causing Fermi level-pinning for Sb on GaAs, and the determination by Ph. Avouris and R. Wolkow (also IBM, Yorktown Heights) of the changes in the energy structure of Si(111) upon reaction with NH_3. Such studies demonstrate that

the ultimate scientific impact of STM will be much broader than its already important uses for structure determination.

Molecular Imaging

Interest in molecular imaging ranges from chemically absorbed sub-monolayers of small molecules through complex systems such as liquid crystals or Langmuir-Blodgett films to biological macromolecules such as DNA. Imaging will depend on the tunneling spectrum for each individual system, and clearly can become very complicated for the largest molecules. Work presented in this area included measurements of well-characterized overlayers of benzene on Rh(111) and of thiols on Au(111). Systemic extensions of such work to larger and larger molecules are planned to determine the tunneling mechanisms. Other groups presented results showing that the goal of imaging complex systems is attainable. Structures clearly related to submolecular units were shown for a liquid crystal, for rec-A DNA complexes, and possibly also for ultrathin ploymer films. The results are very promising for future applications of STM in this area. In addition, the Atomic Force Microscopy was shown to be applicable for systems where tunneling conductance is poor.

Electrochemistry

The demonstration by R. Sonnenfeld and P. Hansma (University of California, Santa Barbara) of the feasibility of operating an STM in an electrolytic solution opened the way for direct measurement of the electrodes in an electrochemical cell. Several groups presented results measured *in situ* during electrochemical reaction. A reference electrode was used to allow measurement of the tunneling current in the presence of the larger electrochemical current. T. Twomey et al. (Fritz-Haker Institute, Berlin) showed images of changes in monoatomic steps on a Au(111) electrode during reaction – an indication of the detailed information about the electrodes which is accessible via STM.

Lithography

The limits of resolution in lithography were discussed by A.N. Broers (University of Cambridge). The best useful resolution at present is 30 nm using electron beam lithograpy. However, this technique is still too expensive for production and is primarily used in scientific investigations. He concludes that in spite of its potential resolution of tenths of nm, the STM is at present too slow and too limited in range for production. However, its impact on diagnostics is already being felt. Furthermore its development as a structure-modifying tool is being pursued by many groups. Techniques presented included using current pulses to modify polymer films or the surface directly, and controlled scraping of the surface by the tip. Resolutions down to 50 nm were reported.

Other Applications

A wide range of applications of STM were presented. Here I will only discuss two, which were of particular interest because both extend the reach of STM beyond the pure surface region. The first is the application by C.M. Mate (IBM, Almaden) of atomic-force microscopy to liquid layers. Mate has been able to image both the gas/liquid and liquid/solid interfaces in this way and correlate the structural features. In addition, he has measured Van der Waal's interactions at the liquid surface. By dipping the tip in and out of the liquid to varying depths he has measured capillary forces as a function of depth. His results show real promise for studies of liquids such as lubricant films.

The second subsurface probe technique, developed by L.D. Bell and W.J. Kaiser (Jet Propulsion Laboratory [JPL], is Ballistic Electron Emission Microscopy. This technique can be used to measure the spatial variations of the Schottky-Barrier height of an interface as much as 100Å below the surface. The measurement is performed in a transistor configuration with the STM tip acting as the emitter, the metal overlayer as the base, and the semiconductor substrate as the collector. The tunneling current is measured at the base and used as in standard STM to measure topography. The variation of the collector current with bias voltage is measured separately to determine the Schottky-Barrier height. The technique has been applied successfully to Au/Si and Au/GaAs with 10-Å resolution.

Conclusion

Of necessity, this brief report has neglected a large number of additional exciting applications of STM presented at the conference. These, as well as additional information on the results summarized here, will appear in the conference proceedings in the *Journal of Microscopy*. A general conclusion from the conference is that STM is being applied to a diversity of problems with results of impressive quality. This remarkable progress in just 6 years since Binning and Rohrer presented the first atomic-resolution images obtained by STM.

8/29/88

The 10th International Free Electron Laser Conference

by Douglas J. Bamford. Dr. Bamford is a Research Physicist at Deacon Research, Palo Alto, California.

The 10th International Free Electron Laser Conference was held from 29 August through 2 September 1988 at Kibbutz Ramat Rachel in Jerusalem, Israel. The conference was sponsored by the Israel Academy of Sciences and Humanities, the Israel Ministry of Science and Development, the Maurice and Gabriela Goldschlegger Conference Foundation at the Weizmann Institute of Science, Tel Aviv University, the US Office of Naval Research, and the US Air Force European Office of Aerospace Research and Development. Cooperating Societies included the IEEE/Lasers and Electro-Optics Society, the Optical Society of America, the American Physical Society, the Israel Physical Society, and the Israel Laser and Electro-Optics Society. The conference cochairmen were Avraham Gover of Tel-Aviv University and Victor Granatstein of the University of Maryland. More than 100 scientists from 11 countries participated, including representatives from the US (51 participants), Israel (14), France (14), West Germany (11), the Netherlands (7), Japan (5), Italy (3), UK (2), People's Republic of China (1), and Poland (1).

Roughly half of free electron laser (FEL) activity in the world is carried out in the US (as reflected in the above totals). Only three reports of working FEL devices in foreign countries (one in France, one in the Soviet Union, one in China) were given at the conference, in contrast to the approximately 10 such devices now operational in the United States. However, many foreign devices are in the planning or development stages, and we can expect the American lead in experimental FEL research to decrease in the near future.

In keeping with the aims of this Bulletin, space limitations, and the author's status as an experimentalist, this report will not do justice to the contributions of American scientists or those of theoreticians. The conference proceedings will be published next year in *Nuclear Instruments and Methods in Physics Research* (North-Holland Physics Publishing, Amsterdam).

Ultraviolet FEL Oscillation in the Soviet Union

Perhaps the most newsworthy item of the meeting was a report by Dr. Marie E. Couprie of Université de Paris-Sud (Orsay, France) on a recent trip to the Soviet Union. Researchers at the Institute of Nuclear Physics (Novosibirsk) have constructed an FEL in a bypass of a 350-MeV storage ring. Using a 3.4-meter-long electromagnetic undulator, they have achieved FEL oscillation in the wavelength ranges between 580-690 nm and between 370-440 nm. The end of the latter tuning range represents the shortest wavelength achieved to date in an FEL oscillator. The laser can reportedly operate for 15 minutes at a time, limited by the storage time of electrons in the ring. The Soviet researchers hope to achieve in the future lasing at 330 nm (simply by installing laser mirrors with good reflectivity at that wavelength) and at 210 nm (by operating at the third harmonic of 630 nm). The unfortunate absence of the Soviet scientists precluded a detailed discussion of this device, which clearly relied on major advances in wiggler design and ultraviolet mirror reflectivity. The work will be described in the proceedings of the Novosibirsk Synchrotron Radiation Conference. (For more information, contact Dr. Couprie at the following address: CEA-IRF-DPhG-SPAS CEN Saclay, 91191 Gif-sur-Yvette, France.)

Japanese FEL Development

Yuuki Kawarasaki of the Japan Atomic Energy Research Institute (JAERI) in Tokai summarized the status of nine different lasers in various stages of planning and construction. The projects now under construction cover a wide range of FEL technologies, including storage ring lasers at the Electrotechnical Laboratory in Tsukuba and the Institute of Molecular Science in Okazaki, radio-frequency (RF) linear accelerators at Osaka University and at Tokai, a double-sided microtron at Narashino, and a superconducting linac at JAERI. The storage rings are already being used for synchrotron radiation research, but FEL oscillation has not yet been achieved. The Japanese program is ambitious and clearly well-funded. By the time the lasers under construction are built (2 to 3 years from now) their program will be second only to the American one in scope.

FEL Activity in the People's Republic of China

Dr. Liu Shenggang of the University of Electronic Science and Technology of China in Chengdu gave a survey of FEL activity in China. One FEL amplifier is already in operation: a millimeter-wave device which has demonstrated 47 decibels (dB) of gain and 2 percent extraction efficiency. The output power has been measured

as a function of wiggler magnetic field and wiggler length, and spectral properties of the radiation have been measured. Two other shorter wavelength FEL devices are under construction at Refei and Beijing. The latter facility is expected to be operating at a wavelength of 10.6 microns by 1990. The Chinese do not appear to be catching up to the US nearly as quickly as the Japanese are.

FEL Activity in France, the Netherlands, and West Germany

The French currently have one working device, which was described by Dr. J.M. Buzzi of Laboratoire PMI, Ecole Polytechnique, Palaiseau. This millimeter-wave device has two unique features. A 1-mm-diameter graphite tube is used to minimize the emittance of the electron beam, and a copper sulfate solution around the wires contained in the helical wiggler causes the tapering of wiggler magnetic field. The output power, spectral characteristics, and gain characteristics of the device have been measured. The unusually high gain of 2.9 dB per centimeter is attributed in part to optical guiding effects.

Two other French devices are under development. A storage ring laser is being built at the Super-ACO storage ring at Orsay, as described by that project's Marie E. Couprie. Spontaneous radiation measurements on the permanent magnet optical klystron agree well with theoretical predictions, lending confidence to the expectation of 10 percent gain in the visible and UV regions of the spectrum. The French group constructed the first working storage ring FEL (now decomissioned) at the ACO storage ring, and they can be expected to remain leaders in storage ring FEL technology (the most promising technology for short-wavelength FEL operation). Jean-Michel Ortega of Université Paris-Sud, Orsay, described another project at Orsay, an infrared laser based on a dedicated RF linear accelerator. A major innovation in this light source will be the use of a wiggler in two sections: a linear section to provide high gain and a fast turn-on, and a tapered section to provide high saturated power. The laser will be the cornerstone of a user facility at Orsay, in addition to advancing the state of the art in RF-linac-based FEL technology.

Researchers in the Netherlands are undertaking two major FEL projects. Dr. P.W. van Amersfoort of the FOM Institute for Plasma Physics in Nieuwegein spoke of progress on developing an infrared laser which will be used for experiments in plasma diagnostics, nuclear magnetic resonance, and surface spectroscopy. The Dutch workers have taken advantage of the demise of the only experimental FEL program in the UK by inheriting the undulator from that project. Two significant innovations of great benefit to FEL users include the use of four distinct wiggler sections (to allow rapid tuning of the laser over large wavelength regions) and the use of an intracavity etalon to reduce the linewidth of the laser. The device is expected to lase in the 8- to 80-micron wavelength range by 1990. Dr. G.J. Ernst of the University of Twente outlined a proposal to build a laser based on a racetrack microtron electron beam source, using subharmonic bunching to get around the space charge effects which normally limit the performance of such devices.

West German FEL research was not adequately represented, as no talks from West Germany and only two poster papers were given. One group at the Nuclear Physics Institute at the Technische Hochschule Darmstadt is building a near-infrared FEL based on a superconducting 130-MeV electron accelerator, and another group at the Max-Planck Institute for Quantum Optics in Garching is in the early planning stages for a device lasing in the extreme ultraviolet and soft x-ray regions of the spectrum, using a high-intensity infrared pump laser instead of a magnet structure as the laser wiggler.

FEL Research in Israel

An impressive demonstration of the feasibility of using infrared pump lasers as a laser wiggler (important for short-wavelength lasers such as the one just mentioned) was given during the conference tour of Tel Aviv University by Z. Sheena. Two counterpropagating carbon dioxide laser beams were overlapped with an electron beam. The lasers set up a ponderomotive potential. To trap the electrons in that potential, a small dc axial electric field was applied to the electron beam, and the resulting effect on the bunching of the electrons was measured directly using time-of-flight spectroscopy. The experiment worked flawlessly in a room full of conference participants; a subsequent talk by Dr. Sheena proved that the experiment was well-understood theoretically.

Later in the conference tour the participants saw the electrostatic accelerator facility at the Weizmann Institute of Science in Rehovot. A free electron laser using one of the accelerators is under construction. Dr. Avraham Gover described an ambitious Israeli program to develop applications of that laser, including experiments in laser fusion, materials processing, isotope separation, medicine, and remote sensing. He emphasized that the electrostatic accelerator, in combination with new "microwigglers" now under development (which allow shorter wavelengths to be produced at a given electron energy), should allow the electrostic accelerator to be competitive with lasers based on other kinds of accelerators now working in the US and Europe. Because the electrostatic accelerators at the Weizmann Institute are state of the art, the Israelis have a good chance to make this alternative approach a success.

Technological Developments

The technology of free electron lasers is still evolving. A few of the most important developments discussed at the meeting deserve mention here. Microwiggler designs, which are important for generating shorter wavelengths, were described by Victor Granatstein (University of Maryland), George Bekefi (MIT), and H.P. Freund (Science Applications International Corporation). The Maryland group is also pioneering the use of a "sheet" electron beam to allow the wiggler magnets to be placed closer together (allowing a large magnetic field to be applied even when the wiggler period is smaller). Photocathodes are being used in place of more conventional cathodes to produce electron beams of higher brightness, as described by Bruce Carlsten (Los Alamos National Laboratory) and A. Michalke (Bergische Universität, West Germany). Researchers are learning to narrow the spectral distribution of FEL's (important for users who wish to do spectroscopy) using a variety of techniques including placing gratings in the laser cavity (Jon Sollid, Los Alamos), cavity length detuning and careful stabilization of electron beam energy (Roger Warren, Los Alamos), and use of longer electron pulses (I. Kimel and Luis Elias, Center for Research in Electro-Optics and Lasers, University of Central Florida, Orlando, and G. Ramian, University of California at Santa Barbara). Third harmonic lasing to produce shorter wavelengths is included in the plans for a number of laser systems, and has been demonstrated experimentally for the first time by Steven V. Benson (Stanford University Photon Research Laboratory, Stanford). Optical guiding will be needed to confine an FEL optical beam traveling through a long wiggler in experiments requiring shorter wavelengths or higher powers; convincing evidence that this effect is well understood was given by John Edighoffer and coworkers (TRW/Lawrence Livermore Laboratory). Numerical simulations of FEL performance are crucial to our understanding of FEL physics; this is especially important when planning the construction of new devices which will operate in previously untried parameter regimes. Numerous speakers dealt with such simulations; the most impressive of these were E.T. Scharlemann (Lawrence Livermore) and John Goldstein (Los Alamos) because of the excellent agreement between experiment and theory. (One can never be sure about the validity of calculations which are not checked against hard experimental numbers.)

The FEL Prize

At the conference dinner the first FEL Prize was awarded to Dr. John M.J. Madey of the Stanford Photon Research Laboratory. The choice was an obvious one, since Madey was the inventor of the FEL and has been a leader in the field from the demonstration of the first working device in 1975 up to the present day. Unfortunately, Dr. Madey was unable to attend the conference. In his absence, Dr. Luis Elias gave an amusing account of the early days of FEL research at Stanford. Madey had to overcome a considerable amount of skepticism about whether his FEL device would ever work. His eventual success proved that he understood FEL physics better than the skeptics, and should provide a model of persistence for all people working in this area of research.

Conclusions

FEL research is on the threshold of a new era, in which the applications of the lasers (to scientific research and to solution of real-world problems in medicine and industry) will become more important than the understanding of the devices themselves. The most commonly repeated theme at the conference was "We don't have a working device yet, but in a couple of years we will have a wonderful FEL user facility." All participants are eagerly looking forward to hearing more about FEL applications at the next three conferences (at Naples, Florida in 1989, Paris in 1990, and Los Alamos in 1991).

10/4/88

SUPERCONDUCTIVITY

NATO Advanced Study Institute on Superconducting Electronics

by M. Nisenoff and J.C. Ritter. Dr. Nisenoff is with the Electronics and Technology Division, and Dr. Ritter with the Condensed Matter and Radiation Sciences Division, of the Naval Research Laboratory, Washington.

Background

A NATO Advanced Study Institute (ASI) on Superconducting Electronics was held at the il Ciocco International Conference Center near Castelvecchio Pascoli, a small town about 70 kilometers north of Pisa, Italy. The participants came from most of the NATO countries as well as from several non-NATO ones. Among the NATO countries, there were attendees from Belgium (3), Canada (3), France (2) West Germany (8), Italy (12), the Netherlands (4), Norway (1), Spain (2), Turkey (3), the UK (11) and the US (23). Participants from non-NATO countries included Sweden (5), Japan (2), and one each from India, Argentina, Australia, and the People's Republic of China. This group was very diverse and extremely bright and as a result they asked many interesting and challenging questions and interacted very well with the lecturers and with each other. Many indicated that they intend to maintain contact with their fellow participants after the end of the ASI.

The ASI started on 28 June 1988 and continued for 2 weeks. Most of the meeting was devoted to reviewing superconductivity, superconducting tunneling phenomena, and the various electronic applications which rely on the unique properties of the superconducting state to provide electromagnetic sensors and analog and digital circuits of unparalleled performance. The ASI focused on the demonstration of superconducting electronic devices and circuits using conventional, low-temperature superconducting materials. The final 2 days were directed at the potential for electronic applications of the recently discovered high-temperature superconducting (HTS) materials with transition temperatures in excess of 90 K and a country-by-country review of current research and programs in both low- and high-temperature superconductivity.

The ASI on Superconducting Electronics was conceived about 2 years ago by Nisenoff (coauthor of this report) and Dr. Harold Weinstock, Program Manager for Superconductivity at the Air Force Office of Scientific Research (Bolling AFB, Washington, DC), prior to the announcement of the breakthrough in T_c by Bednorz and Muller. At that time, during the summer of 1986, it was felt that there was a need for an ASI dealing with superconducting electronics (the previous one had been held in 1978) to introduce the next generation of researchers to the great potential superconductivity offers in ultrasensitive low-frequency magnetic sensors; quantum-limited microwave and millimeter wave mixers and detectors; very low electrical loss; zero-dispersion signal transmission lines; and extremely high-speed, low-power-dissipation digital devices for logic and memory circuits.

After the experiments of Bednorz and Muller and those of Chu and coworkers, who discovered superconductivity above liquid nitrogen temperatures, the popular press and, unfortunately, even the scientific and technical literature began to publish information on the applications of HTS which, in many cases, were vague, impractical or totally wrong. It was clear the authors were not familiar with what could be done with low T_c superconducting materials and what the limits are for any superconductor. Thus, the HTS revolution made it even more imperative that the next generation of researchers in superconductivity have a solid and correct understanding of the principles and performance capabilities of superconducting electronic sensors, devices, and circuits built with the presently available low-temperature materials as well as the HTS materials which are being and will be developed in the future.

Lectures

The Directors of the ASI selected for lecturers 13 outstanding experts in various aspects of superconductivity, superconducting electronics, and cryogenic refrigeration. Although the professional lives of these lecturers have changed drastically during the 2 years since they originally had accepted the invitation to participate in the ASI, all of them kept their commitments. Many of these lecturers had assumed additional responsibilities in for-

mulating their institution's and their country's research activities on superconductivity. However, they came to the ASI because they realized the impact that a sound and correct understanding of superconducting electronics would have on the next generation of researchers.

The 13 lecturers were all authorities in their fields of expertise. They came from nine NATO countries and from Japan. J. Clem (University of Iowa, Ames) reviewed the theory of conventional as well as the HTS superconductors while Y. Bruynseraede (University of Leuven, Heverlee, Belgium) discussed Giaever and Josephson tunneling and quantum interference effects. The fabrication of superconducting tunneling devices, which is central to superconducting electronics, was reviewed by G. Donaldson (University of Strathclyde, Glasgow, UK) and cryogenic refrigeration by C. Heiden (University of Geissen, West Germany). J. Clarke (University of California [UC] at Berkeley) lectured on the concepts of the superconducting quantum interference devices (SQUID's) and the use of SQUID's in geophysical exploration and as ultralow-noise amplifiers. The use of SQUID's in biomagnetic research and medical applications was described by G.-L. Romani (Institute of Electronics and Solid State – CNR, Rome, Italy). G. Donaldson also described applications for SQUID instrumentation not covered by Clarke and Romani, and the issue of chaos in Josephson devices was addressed by N. Pedersen (Technical University of Denmark, Lyngby, Denmark). K. Gundlach (Institute of Millimeter Wave Radio Astronomy, St. Martin d'Heres, France) reviewed the use of superconducting tunnel devices as mixers and detectors of millimeter-wave radiation and described how they have become the technology of choice in millimeter-wave radio astronomy applications. The use of arrays of Josephson devices as signal sources in the microwave and millimeter-wave frequency region of the spectrum was described by J. Lukens (State University of New York, Stoneybrook). The use of superconductivity in analog and digital signal and data processing applications was treated by T. Van Duzer (UC, Berkeley, California) and by H. Hayakawa (Nagoya University, Nagoya, Japan). The status of the three-terminal device or the so-called "superconducting FET" was reviewed by T. Klapwijk (University of Groningen, the Netherlands). Finally, a review of what is known about tunneling into the HTS materials was given by A. Barone (Institute of Cybernetics – CNR, Naples, Italy). All together, there were approximately 38 hours of formal lectures along with "workshops" each day for extended discussions and question and answer periods. These workshops were very well received, the discussions lively, and the participants appeared to appreciate the opportunity to interact with experts of the caliber of the lecturers.

Conference Emphasis and Future Applications

The major emphasis during the ASI was on the principles of superconducting electronic devices and circuits and their implementation in conventional low-temperature materials. However, the potential impact of the recently discovered superconducting materials with transition temperatures above 30 K could not be ignored. Accordingly, the 2 final days of the ASI were specifically devoted to these recent developments. J. Clem reviewed the many theories that have been advanced to account for superconductivity at these heretofore unexpectedly high temperatures, while A. Barone described the many and often contradictory experiments on tunneling experiments into these new materials and the confusion over the values for the superconducting energy gap deduced from these experiments. There was also one session in which representatives of several of the nations represented at the meeting gave overviews of the dramatic increase in superconductivity research in their countries since the discovery of Bednorz and Muller.

On the final day, there was a panel discussion about the impact of HTS on the overall progress in superconducting electronics. A number of panelists indicated that they were very encouraged and pleased by the increase in activity and governmental financial support but all were concerned about the unevenness of this support and the continuous vacillations shown by the government agencies responsible for directing these programs. All agreed that it would be desirable to have an adequate level of funding that was guaranteed for a number of years – something like 5 – to ensure that the science and technology could be properly expedited. All agreed that this would be a utopian world which all wanted but none really expected.

It is clear that high-temperature superconductivity will have a great impact on the use of superconducting electronics due to the reduced refrigeration requirements. In many applications, operating at temperatures of the order of one-half to two-thirds of the transition temperature would be satisfactory while for the ultimate in performance, one would want to work at much lower temperatures (even with the high T_c materials) – for example, possibly at 28 K, the boiling point of liquid neon, or even 4 K, the boiling point of liquid helium. A trade-off of performance vs. operating temperature will be crucial in determining an optimum operating temperature for any given HTS device or circuit application.

Once HTS device technology is developed, low-temperature superconducting device and circuit concepts will be implemented in HTS. However, one must also look for new device and circuit concepts which exploit the unique properties of the HTS materials – possibly, for example, the electrical anisotropy. In addition, since

ibly, for example, the electrical anisotropy. In addition, since many semiconductor devices operate substantially faster and with lower power and noise in the 30 K to 100 K temperature range, hybrid circuits of superconductor devices and semiconductor devices need to be evaluated: possibly superconducting interconnects between semiconductor chips may be the first example of hybrid technology. Applications of superconducting and semiconducting devices together in space appears to be a particularly attractive option because new capabilities can be gained for spacecraft, but use of HTS materials will greatly ease the refrigeration requirements. Superconducting wiring on chip does not appear to be particularly promising at this time. Integrated superconductor-semiconductor device structures appear to be in the distant future less the high processing temperatures required to optimize the properties of HTS materials can be reduced. These high processing temperatures appear to be incompatible with preserving semiconductor device properties. It was also stressed by a number of speakers that as soon as any HTS application is implemented, it must be introduced into a field-deployed instrument to demonstrate the viability of HTS electronic technology. The 50-fold increase in cryogenic fluid lifetime in the field gained by substituting liquid nitrogen for liquid helium will greatly increase the possibility of field applications for HTS devices. The general public and the funding agencies must be shown that this technology is real and practical. Results that address problems and issues that are of commercial or general interest must be pursued rigorously to insure continued support, both financial and moral, for future research and development of high-temperature superconductivity and superconducting electronics.

Proceedings

The Proceedings of The NATO Advanced Study Institute on Superconducting Electronics, will be edited by the ASI Co-Directors, M. Nisenoff and H. Weinstock, and will be published early in 1989 as part of the NATO Advanced Study Institute Series by Springer Verlag, (West) Berlin.

10/5/88

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